AMERICAN SOCIETY OF CIVIL ENGINEERS.
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TRANSACTIONS.

599.

(Vol. XXVIII.—June, 1893.)

ADDRESS AT THE ANNUAL CONVENTION AT CHICAGO, ILL., AUGUST 4TH, 1893.

By WILLIAM METCALF, President Am. Soc. C. E.

Gentlemen of the American Society of Civil Engineers:

It would seem on this occasion of a general gathering of the nations to celebrate one of the greatest events of history, and to illustrate by their products the wonderful advances made by men in this most enlightened age, as if the annual address should deal more in a general view than in a specific rehearsal of the events of a year, or of the works alone of the present day.

So far as we are informed by history, or as we can learn by the study of ancient ruins, we know that there have been always great engineers in the civilized world.

From the time when man was first directed to go forth and subdue the earth, to the present day, we know that men have always been engaged in gigantic efforts either to destroy one another, to better the condition of the people, or to rear useless monuments to pride and vanity.

Such efforts continue to this day; but mainly now, we may pride

ourselves, they are directed in one way or another for the betterment of mankind, by a reduction of exhausting toil, and by a wider diffusion of comforts.

What better illustration could we have of the power of engineers in the present day than the wonderful "White City," which is so much admired by all? Here adaptability, roominess, comfort and convenience are made beautiful in every detail by the most perfect art.

Out of the swamp has sprung up, as it were, in a night, this marvelous city, outdoing the imaginings of the Oriental mind and paling the light of Aladdin's lamp.

Among the ancients, we have abundant evidence that the Egyptians carried out vast works of irrigation, to increase the productiveness of the land; the Jews paid much attention to the supplying of an abundance of pure water for the inhabitants of their towns, and built great storehouses for food products; their works unearthed in recent years show that their engineers were men of much ability.

The Romans carried out such works to an extent, and added remarkably well-built roads to a degree that excite the admiration of all to this day.

The Greeks carried art and luxury to such perfection that we of today feel that we can only admire and imitate.

From the time of the destruction of the Roman empire to nearly the time of Columbus, there was stagnation in all of the arts, and but little progress was made in any direction; this is called the dark age in history, yet the light of civilization, of art and of engineering, was kept alive by a body of men who ostensibly left the material world to give up their minds to the spiritual, and who yet preserved the knowledge that enlightened the people when they were aroused to a consideration of better things than mutual destruction. Among these monks was formed a mendicant order called Pontifex, or Bridge-Builders; this order continued for several centuries and wound up its work in one Romain, who, after previous good service under Colbert, became one of the earlier engineers in the Corps des Ponts et Chaussées of France.

The Pontifex may be called the first Institution of Civil Engineers of which we have any knowledge.

At the time of Columbus the Pontifex were of little repute, if, indeed, they were known at all; engineering was devoted mainly to architecture; architecture chiefly to the building of churches and

palaces; art was given up to the adornment of these, and little heed was given to the welfare of the people.

Yet there were great men and brave men in those days, of which we need no better proof than a glance at the copies of the funny little caravels that brought the discoverers to our shores, across the then unknown seas.

To all who saw these caravels lying in the Hudson River beside the great steam vessels of to-day, nothing need be said about the advances of engineering in the last 400 years.

The history of four centuries lay there epitomized, to be taken in at a glance. And even if the great fleets lying there were machines of destruction, compared to the works of peace on all sides of them they were as nothing.

The very power of these war vessels makes for peace; the skill, the ingenuity and the destructiveness developed in the works of the naval and military engineers are all in favor of peace; these works are so destructive and so enormously expensive that the nations are growing afraid of war, so that the very power of these engineers tends to the ruin of their branch of the profession, and we welcome them into our societies gladly as brother engineers and promoters of harmony.

Of the future of engineering, both as a lucrative profession and as a promoter of good, much might be said.

The Siberian railroad across Asia, to be followed by many thousands of miles of branch lines, must certainly arouse the misty East from its lethargy, and animate those great peoples with modern energy and the spirit of advancement.

The building of railroads and opening of water-ways into and through the wilds of Africa will bring light into the "Dark Continent," put an end to the terrible cruelties which are practiced upon inoffensive peoples and dispel the terrors of ignorant superstitions. The building of the trans-Andean railroad, and the cutting of the Isthmean canal, will unite the western hemisphere into a brotherhood of peaceful, happy nations; for before these works are completed, our military members will have made war altogether too expensive for sensible people to indulge in.

But if the building of more railroads and the digging of more canals are to be considered rather as advancing upon good old lines than real development, there is much other work for the engineer to

do in the way of true development. The engineer is the guide, or the pilot, of human energies; he has on one hand the vast mass of laborers to organize and teach, to produce the greatest results with the least effort.

He has the great army of mechanics ready to furnish him with every useful tool he can call for, to increase efficiency and reduce cost. He has also the smaller, but most potent body of men, the scientists, to make known the unknown, to open new roads, and to discover the causes or sources of danger, such as the all-devouring bacteria, "greater than an army with banners," which the engineer must destroy for the good of the people.

A Crookes to point to the powers of the ether; a Tresle to guide him to the development of the tremendous forces of electricity; a Langley to show him how to navigate the air; Roberts-Austen, Osmond and others to see into and read the mysteries of the useful metals, and many others in all of the walks of science probing and searching Nature for her truths.

Many of their discoveries which appear as toys now are potent with great gains to future generations; although they are but small slits now admitting feeble rays of light, the wedges are entered, and the doors will be opened for great advances in the future.

The steam engine, the great modernizer, in all of its present perfection, is too slow, too expensive, too wasteful of power. Man must have something better; science will point out the way, and engineers will apply the science for the good of man. Engineering, then, is much more than the designing and building of structures, ships, roads, and canals; it involves the economic use of labor on one hand and the proper application of capital on the other; the one must be employed fairly and justly, and the other must be applied so as to yield a reasonable return.

That engineers have been successful in both is shown abundantly in the facts that we have now the cheapest, quickest and safest means of transportation the world has ever known.

We have the most economical and best distribution of food, clothing and all of the comforts of life, and in many ways the most even distribution of wealth. By means of the almost instantaneous spread of intelligence, and by quick modes of transit of great quantities of material, severe or long-continued famines have become almost impossible in the enlightened parts of the world.

So, too, a knowledge of sanitary laws enables us now to meet and suppress many epidemic or contagious diseases, which in the time of Columbus would have swept over the earth unresisted, decimating the nations until the virus was exhausted or all weak persons were carried off.

These are the grandest triumphs of engineering; they are the beneficent effects of the great works of engineers. Huge bridges and magnificent structures of all kinds appeal to the eye and excite admiration; the greater comfort and well-being of the people appeal to the better feelings and should excite gratitude.

More than 2 000 years ago a sage wrote that the mechanics are the men who will maintain the state of the world; true then, the statement is equally true to-day, and the engineer is but the highest development of the mechanic through the evolution of the centuries. He is the civil, the mechanical, the mining, the electric, the military and the sanitary engineer; he stands as the guide and the arbiter, just to labor on one side and honest to capital on the other. If social questions are out of his province and he may not meddle with them, he may, at least, and he will, be true to his high position and great trusts, and so help to hasten forward that era to which all eyes are turned, the era of "Peace on earth, good will toward men."

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600.

(Vol. XXVIII.—June, 1893.)

EROSION OF RIVER BANKS ON THE MISSISSIPPI AND MISSOURI RIVERS.*

By J. A. Ockerson, M. Am. Soc. C. E.

Read June 21st, 1893.

A general survey of the Mississippi River from Cairo, Ill., to Donaldsonville, La., was made by the Mississippi River Commission during the years 1879 to 1883. This comprised a system of secondary triangulations, carried out with all the refinements usual in such work, by means of which numerous stone monuments were located at frequent intervals along the river, to serve as initial points for all future surveys. On these points careful topographic surveys were based and additional stone survey marks were set, marking sections of the channel (*thalweg*) at intervals of 3 miles along the river. On these lines there were usually placed four stones, one on each side of the river and about ⅓ mile from it, the others being about ½ mile farther back. In the survey these lines are called stone lines.

* Discussions on this paper received before November 1st, 1893, will be published in a subsequent number.

A line of precise levels was also carried along the river, and numerous bench marks placed. From these the elevations of the stones on the stone lines and the secondary points were derived. It will be seen, then, that a very large number of points were established whose positions and elevations are well determined. By using these fixed points in new surveys, it becomes an easy matter to determine the changes in bank line, with a great degree of accuracy, for all time to come.

In the fall of 1891, it was deemed advisable to investigate the condition of these marks, and, at the writer's suggestion, there was coupled with it a re-determination of the bank lines in the bends. The length of river covered by this investigation is about 885 miles. A brief report on the subject was made and published in the annual report of the Mississippi River Commission for 1892.

In November, 1892, the writer made a trip over this portion of the river at a very low stage of water. Careful notes of the character of the banks and the nature of the material composing them were made, and it was thought that the subject, with the new facts elaborated by further study, would be of sufficient interest to present before the Society. Through the courtesy of Lieutenant J. C. Sanford, Secretary of the Missouri River Commission, who kindly placed their maps at the disposal of the writer, the study was extended in a similar way over some 800 miles of the Missouri River.

Every one who has traveled on these rivers has doubtless heard of the enormous and rapid changes that are continually occurring, and the impression is given out that the entire alluvial plain has been occupied by the bed of the streams in quite recent times ; that the river was there yesterday, is here to-day, and will occupy a different bed to-morrow. The genial pilot will tell you that the prow of his steamer has passed over "every foot of the ground from yonder clump of big trees," now 10 miles inland, to the present location of the channel. In short, every one familiar with the rivers knows that bank erosion is constantly going on, and, although large in amount, nearly every one whose knowledge does not come from actual measurements has an exaggerated idea of its extent.

It is believed that these surveys furnish the first opportunity of an accurate determination of the amount of erosion, and may throw some light on the conditions affecting this amount. It is a matter of much

regret that the importance of establishing fixed points had not occurred to Humphrey and Abbot during their extended investigations of the physical characteristics of the river. It would have given us a much broader base for our studies, and, consequently, more well-determined constants to aid in the solution of the problems of regulation and control of this great river. We have really only a period of about 10 years during which the regimen of the river has been carefully noted and recorded, and during that time many important principles have been worked out, and facts have taken the place of theories.

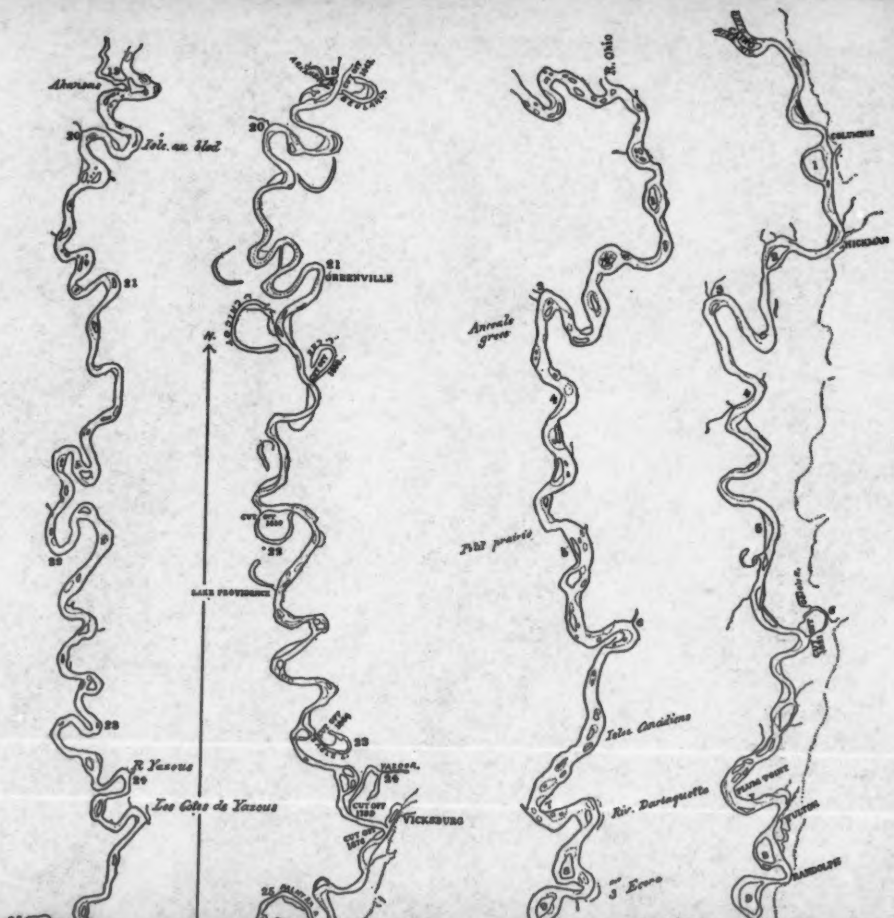
Other important questions can be settled only by continuing the investigations through a much longer period of time, for the changes in the physical condition of the river, if they really exist, must necessarily develop very slowly. While we are impressed with the radical changes that occur in a single locality, we are still unable to grasp the sum total or resultant effect on the whole stream without an extended series of observations.

Lateral Movement of the Bed of the River.—In order to show that the lateral oscillation of the stream is really confined to rather narrow limits, a map (Plate L) has been prepared showing the river as it was in 1768 and in 1893. The early map was traced directly from Captain Philip Pitman's "Early Settlements on the Mississippi, with Plans and Draughts," published in London in 1770 (loaned for the purpose by Colonel George E. Leighton). The map of the last date was reduced with pantograph to the same scale as the former, from charts based on accurate surveys made by the Mississippi River Commission.

In this comparison it should not be claimed that the old map will bear the test of rigid measurements, as the methods in use at that early date were very crude, and doubtless Captain Pitman's force was a very small one. In comparing with the maps of Lieutenant Ross, Collot and others of about the same period, it is readily seen that the work is entitled to the credit of being a careful reconnaissance of high grade, in which the important features and many details were very well sketched. In order to facilitate the comparison, corresponding features in the two maps are marked with the same numerals.

The first striking feature in this comparison is the remarkable stability of the larger islands and the very marked similarity of the bends.

Beginning at the mouth of the Ohio River and moving southward,



20
21
R. Yazous
24
Les Cotes de Yazous
25
N.
GREENVILLE
LAKE PROVIDENCE
VICKSBURG
R. Ohio
Petit prairie
Riv. Dartaquette
COLUMBUS
HICKMAN
FULTON
RANDOLPH

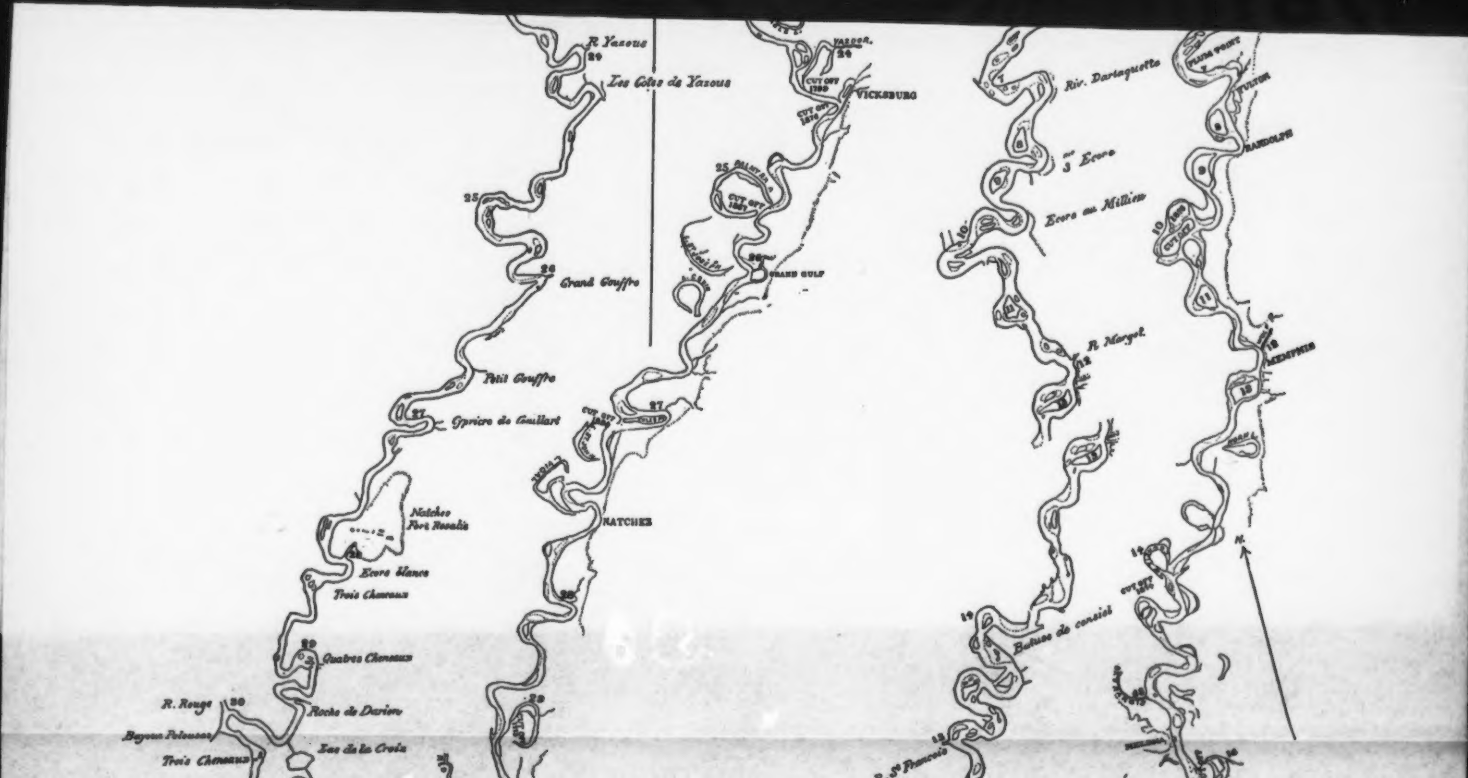

R. Yazous
Les Côtes de Yazous
Grand Gouffre
Petit Gouffre
Ecore Blanche
Trois Chenaux
Quatres Chenaux
Roche de Darien
Lac de la Croix
R. Rouge
Trois Chenaux
Bayoux Poloussa
VICKSBURG
CUT OFF
GRAND GULF
NATCHEZ
Riv. Dartaquette
3me Ecore
Ecore au Millien
R. Margot
Baluse de conseil
R. St Francois
RANDOLPH
MEMPHIS
N.

PLATE L.
TRANS. AM. SOC. CIV. ENGRS.
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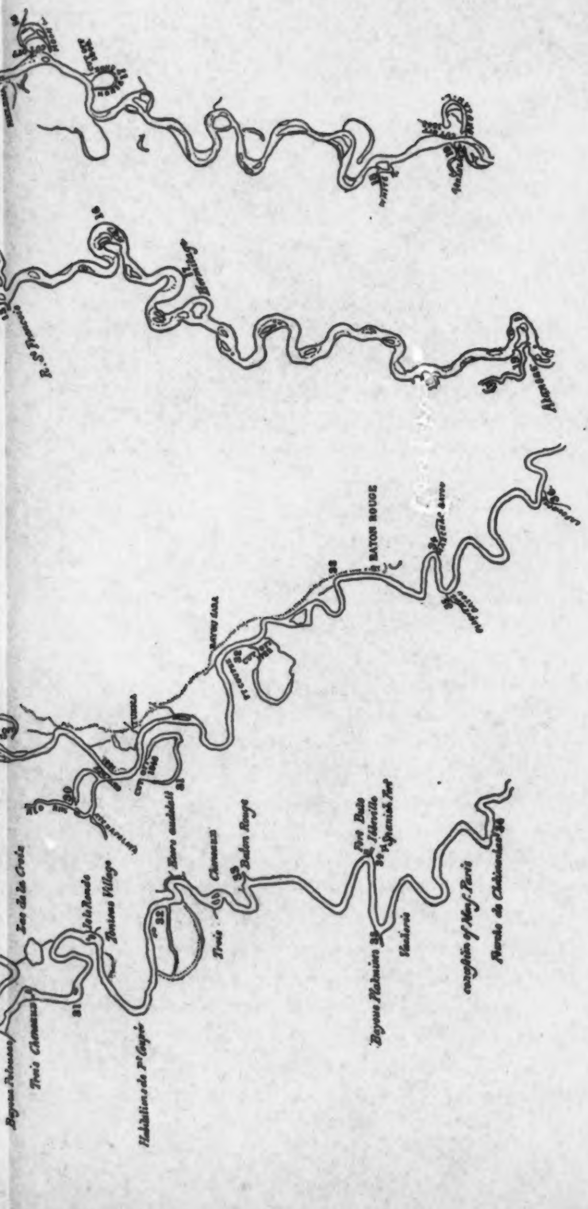
OCKERSON ON EROSION OF RIVER BANKS.



we see in the first left-hand bend the nucleus of the island at the mouth of Mayfield Creek, which we now know as "Island No. 1." Opposite the next right-hand bend is the group of islands which now constitutes Islands Nos. 2, 3 and 4. Just below Columbus, and marked with the numeral I on both maps, is Wolf Island. Island No. 8 is marked 2, and New Madrid Bend 3. Ruddle's Point is 4, and Island 16 is 5. The mouth of the Obion River is shown at 6, and here is the first change of considerable magnitude in the whole stretch of 130 miles. At this point a cut-off occurred in 1821. Then comes the Plum Point Reach (7), which even at that early date was obstructed by the "Isles Canadiens," and bars, very much as it was when the improvement work began in 1882. Islands 34 and 35 are unmistakably identified at 8 and 9, the "Devil's Elbow," cut off in 1876, at 10, Beef Island at 11, and President's Island at 13. Now look back at this reach of 240 miles of river and compare more minutely, and many other features common to both maps will be identified. Every bend and island of considerable magnitude then has its counterpart to-day. Then, as now, the river swept the bluffs at Columbus, Hickman, Fulton, Randolph and Memphis.

Below Memphis are two cut-off lakes, evidently made at a period prior to Captain Pitman's survey. Council Bend (14), cut off in 1874, and Walnut Bend below, are both plainly defined as is the mouth of the St. Francis River (15). None of the early maps show the bluffs at Helena, and perhaps the hills were so far away, and obscured by the dense growth along the river banks, that they escaped notice. This could readily be, even if the distance was short, as the travelers were in small boats, and probably their observations were largely confined to the area lying between the river banks. Moon Lake (16), date of cut-off not known, and Horseshoe Lake (17), cut off in 1848, are easily placed. The mouth of the White River (18), and the Arkansas River (19), are both well defined, Beulah Lake, cut off in 1863, corresponding to the bend at mouth of the Arkansas.

Cypress Creek and Cat Fish Point at 20, and Greenville Bends at 21, are familiar features to river-men. The latter bends seem to have been somewhat elongated, but it is more than probable that part of this discrepancy should be attributed to the work of the early explorer who could easily be pardoned for smoothing out some of the curves where the changes in direction were so sudden and so radical as to be decidedly confusing to any one but a well-equipped surveyor.

Lake Providence Reach with the "Old River" (22), cut off in 1830, shows the same general features at both dates. The Yazoo River (24) then emptied directly into the bend of the river which was cut off about the year 1799. At Vicksburg the hills are reached again, and another cut-off occurred in 1876. Palmyra Bend (25), Grand Gulf (26) and Coles Point (27), are all plainly similar. Note carefully the conditions at 27 at the two periods. Coles Point, a thin neck of land, finally cut off in 1884, stood as a barrier, forcing the river 6 miles to the eastward almost at right angles to its general course. When the cut-off occurred, the width of the neck of land was nearly the same as it was over 100 years earlier. But when the active erosion began, a few hours was sufficient to cut through a deep channel, which is now the main river. Many attempts had been made by means of large ditches to hasten this cut-off, but the river did not break through on the line of the ditches at all, but did its own work unaided. At 29 is the Homochitto Cut-Off, which occurred about the year 1799.

In the vicinity of Red River (30), two artificial cut-offs were made, the upper one under the authority of the United States, by Captain Shreve, in 1831, and the other one by the State of Louisiana, in 1848. "Lac de la Croix" is still in existence, as shown on the map of 1893.

The "Fausse Rivière," cut off about 1710, below Point Coupée (32), is somewhat discrepant, but this is evidently mostly the fault of the explorer who, at that stage, was perhaps taking lessons on his upstream journey in the very difficult problem of sketching a curve accurately from one of its extremities. Other explorers of a few years later show better results in this vicinity. From Point Coupée down, the similarity in the two maps holds good. Profit Island, a short distance above 33, the first island in the river above the Gulf of Mexico, is still a double island as it was when when Captain Pitman sketched it. The City of Bâton Rouge is apparently farther down the river than the early settlement. The bends and bayous below this point are all in harmony on the two maps.

In early reports to the Mississippi River Commission, the writer called attention to the pertinacity with which deep indentations and projecting points retain their identity, although the entire bank line receded several hundred feet. This being true, it may be urged that the similarity of the bends, and the apparent stability of the islands, furnish little or no proof bearing on the movements of the river,

That is, the large islands might move bodily down stream or laterally for long distances. Furthermore, we know that the heads of the islands are eroded, and accretions are added at their lower ends. It is, however, evident that the rate of this movement is not as great as is generally believed.

There is another kind of definite evidence bearing on this question which cannot be ignored, evidence that can come only from an intimate acquaintance with the forests bordering the river and covering densely many of its islands. This evidence was carefully collated in the extensive surveys of the lower Mississippi River, the major part of which were made under the personal supervision of the writer. The huge trees which have withstood the floods and the encroachments of the river for several scores of years, bear mute evidence that the lateral oscillations of the river as a whole are confined within comparatively narrow bounds, even when the unit of time far exceeds in limit the memory of the "oldest inhabitant" or the experience of the oldest pilot.

The data for comparisons of geological periods after the alluvial valley ceased to be an arm of the sea, has never been obtained, and perhaps never will be, and we must therefore be contented with such material as the maps of early explorers give us, with the satisfaction of knowing that future engineers will always have convenient and definite means of studying the changes which occur in the regimen of the river. By this means they will, perhaps, be enabled to determine many of the laws governing the water's ebb and flow, which here produce erosion, there deposit, here flow deep and still in a narrow channel, there broaden out and dissipate the gathered energy in a struggle to maintain openings through several narrow, tortuous channels.

Amount of Erosion and Character of Eroded Banks.—A general idea of the nature and extent of the erosion may be obtained by the study of Plates LI to LV. (The erosion is shown by shaded areas, and the present bank line by a heavy black line.) The borings shown on Plates LI and LV give a good idea of the material composing the banks. This is also further shown in Table No. 1.

The term erosion rather implies a steady wearing away, and in some cases these conditions are fulfilled. But, generally, where changes in bank line are rapid, the process is entirely different. No great

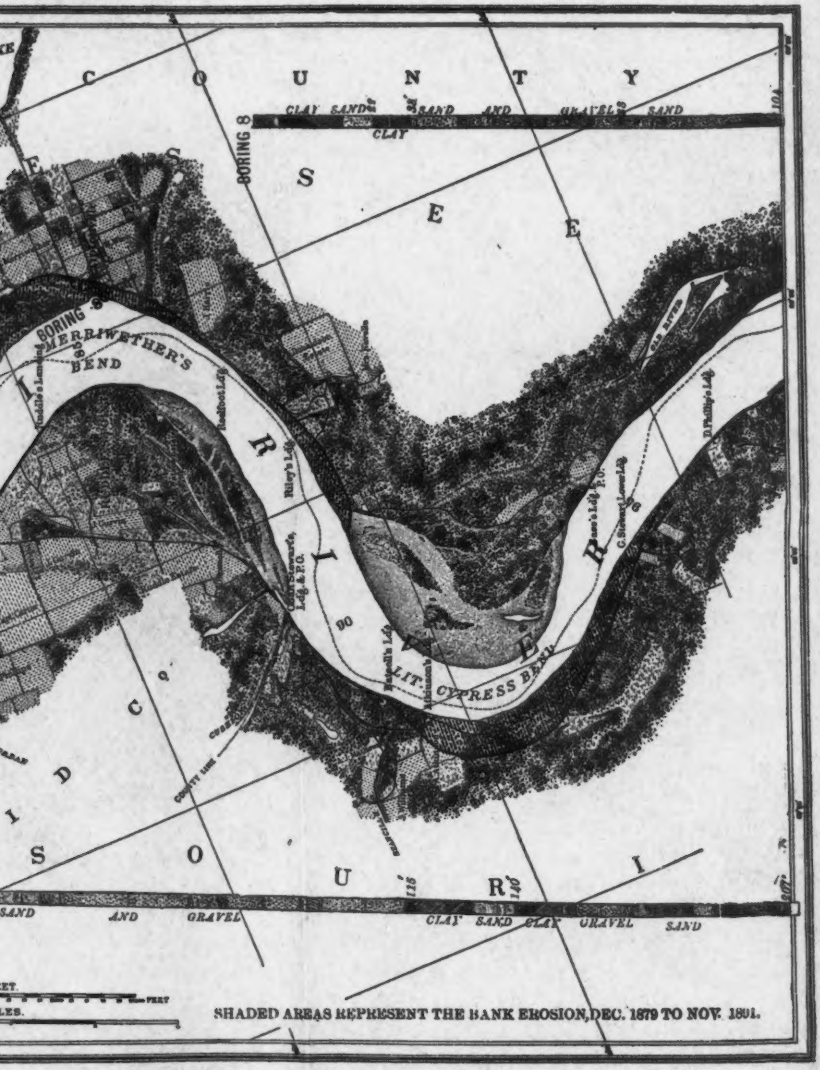
amount of caving occurs at high water. The period of greatest activity is generally found to be during a falling stage, from a little below the medium stage down. The banks being composed of sand and silt, with horizontal layers of clay at irregular intervals, become saturated for quite a distance from the river during the high-water period, and, as the water in the river falls, it carries with it that which has penetrated the banks, and consequently much of the sand which supports the layers of clay. This process is, of course, aided by the drainage from the overflowed lands and the impinging current in the bends. The result is that a large block of ground, sometimes 200 ft. or more in width and perhaps 1 mile in length, settles down bodily several feet. The trees stand vertical for quite a time, gradually settling deeper and deeper as other layers wash out, and the block is finally broken up, disintegrated and disappears. When a narrow neck of land separating the bend finally breaks through, it is called a cut-off.

This neck of land may be quite narrow with a long distance around the bend, consequently the slope across it is much greater than the general slope of the stream. The natural supposition, then, would be that the cut-off would be due to scour from the top. This, however, is rarely the case, and the opposite is more frequently true. That is, the neck is actually built up by deposit. Consequently, the seemingly frail barriers stand for many years, and finally break through in a few hours without warning. More than likely the usual process of undermining, washing out a layer of sand, is the immediate cause of the break. When the surface is once thus broken, the excessive slope in an overflowing stage plays an important part in hastening the demolition of the barriers.

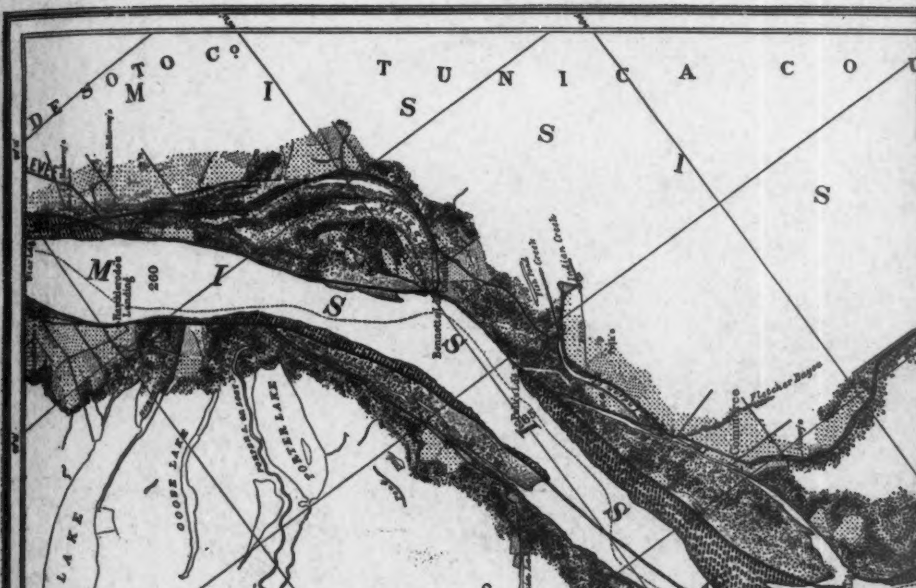
There are a few cases, as at Ben Lomond, 544 miles from Cairo, where the banks are apparently homogeneous sand and silt, where they crumble away rapidly and continuously, the caving face being nearly vertical. There are other places where the banks are apparently homogeneous clay, as at Linwood, 115 miles from Cairo, Deadman's Bend, 730 miles from Cairo, and, in general, all of the river below Bâton Rouge, where there is comparatively little caving. Old Town Bend, 325 miles from Cairo, has always been conspicuous for the great amount of timber standing in the water, several hundred feet from the bank proper. The bank stands about 67 ft. above the *thalweg* of

KENTUCKY
LAKE
BORING
SAND
CLAY
GRAVEL
Lester's Ldg.
Morrison's Ldg.
Nolan's Ldg.
Toney Ldg.
Marr's Landing P.O.
Darnell's Ldg.
NEW MA


CLAY
SAND
SAND
REELFOOT LAKE
Keystone Saw M.
Harrison's Saw Mill
ISLAND No. 10
Toler's Landing
Marr's Landing P.O.
Darnell's Ldg
Williams Landing
Phillip's Landing
Lazelle's Landing
Point Pleasant
BAYOU JORDAN
BORING 21
SAND
SCALE OF FEET.
STATUTE MILES.
NEW MADRID



SHADED AREAS REPRESENT THE BANK EROSION, DEC. 1879 TO NOV. 1891.



SHADED AREAS REPRESENT THE BANK EROSION, NOV 1879 TO NOV 1891.


COUNTY
LEVEE
Fletcher Bayou
COMMERCE CUT-OFF
(1874)
270
275
280
BORDEAUX CHUTE
WALNUT BEND

PLATE LII.
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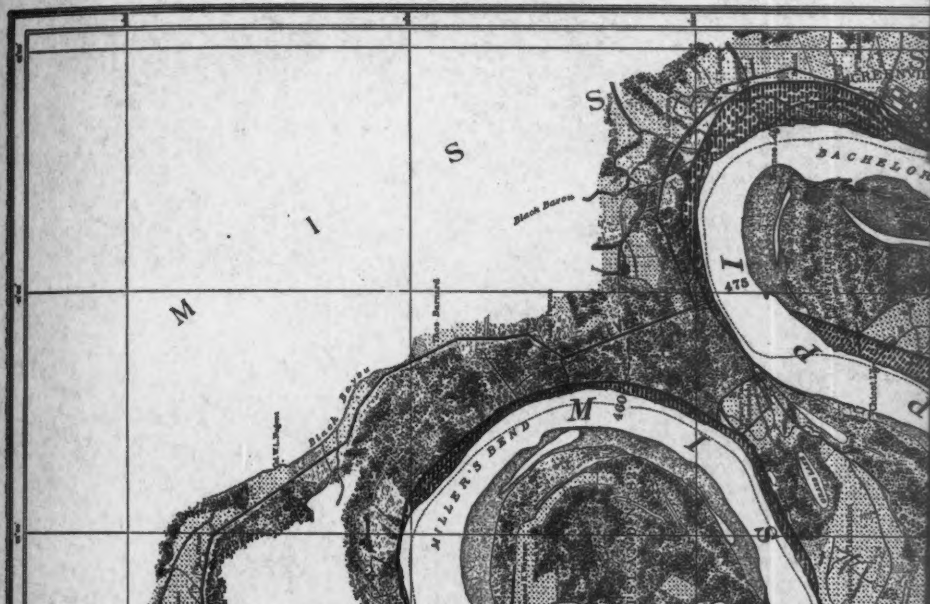

M I S S
Black Bayou
BACHELOR
475
MILLER'S BEND
460
455
465
SPANISH
BEND
LEVEE
LEVEE
LEVEE
450
A R K
A

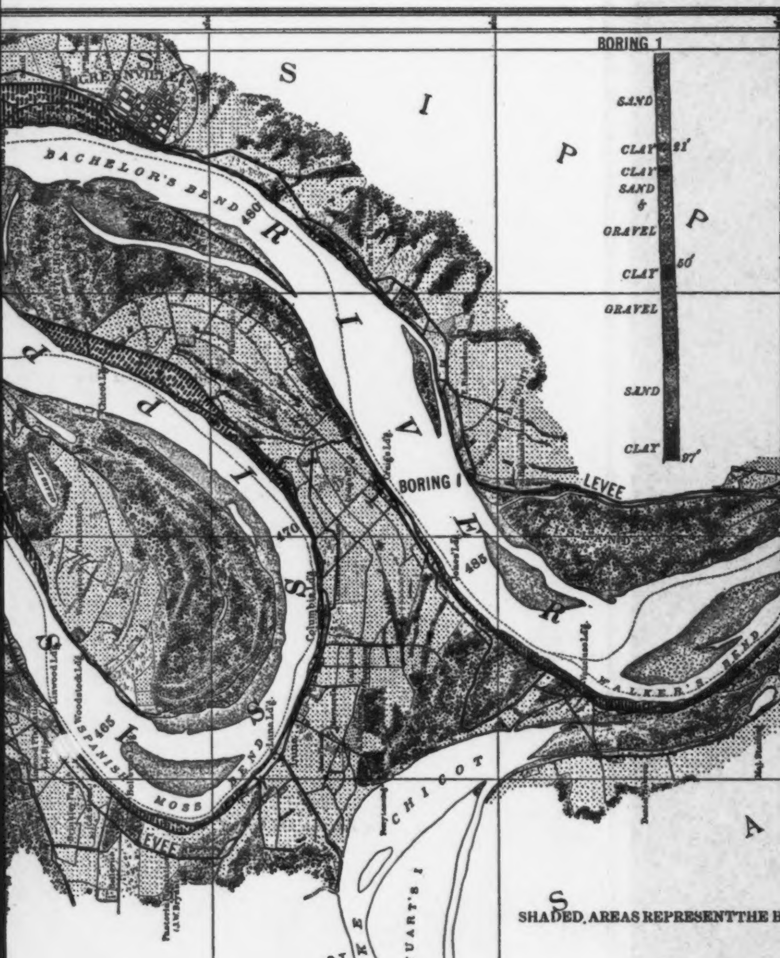
OC
BORING 1
SAND
CLAY 21'
CLAY
SAND & GRAVEL
CLAY 50'
GRAVEL
SAND
CLAY 97'
GREENVILLE
BACHELOR'S BEND
RIVER
BORING I
LEVEE
WALKER'S BEND
SPANISH MOSS BEND
LEVEE
LAKE CHICOT
STUART'S I
SHADED, AREAS REPRESENT THE B
SCALE OF FEET
STATUTE MILES

PLATE LIII.
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CITY OF VICKSBURG
M
S
S
I
WARREN
CENTENNIAL LAKE
I
S
S
S
M
McCUT-OFF in 1876
600
595
MOUTH OF YAZOO RIVER
MADISON
LOUIS
L
O
U
I
S
SHADED AREAS REPRESENT THE BANK EROSION

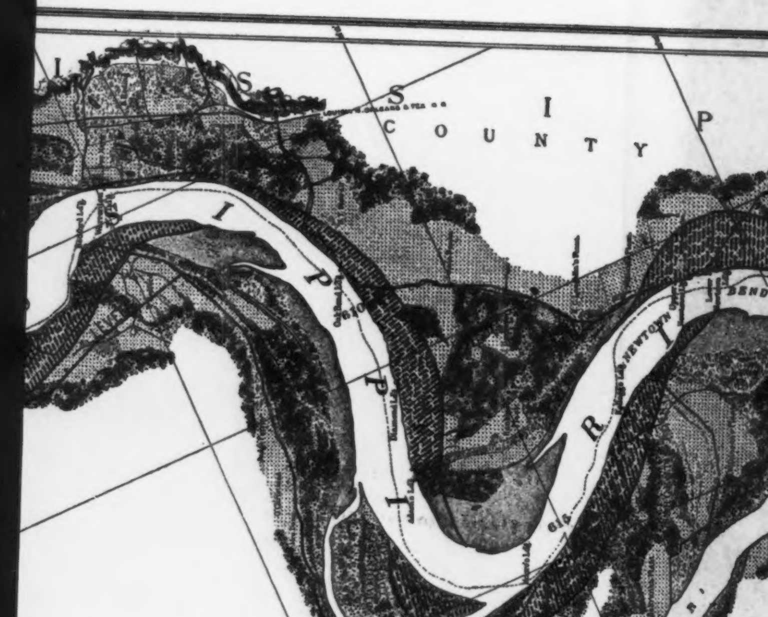
COUNTY
BEND
NEWTOWN
610
615
SON PARISH
LEVEE
OLD RIVER
PALMYRA ISL. No 100
Bayou
THE BANK EROSION, OCT 1881 TO FEB 1892.
SCALE OF FEET
STATUTE MILES

PLATE LIV.
TRANS. AM. SOC. CIV. ENGRS.
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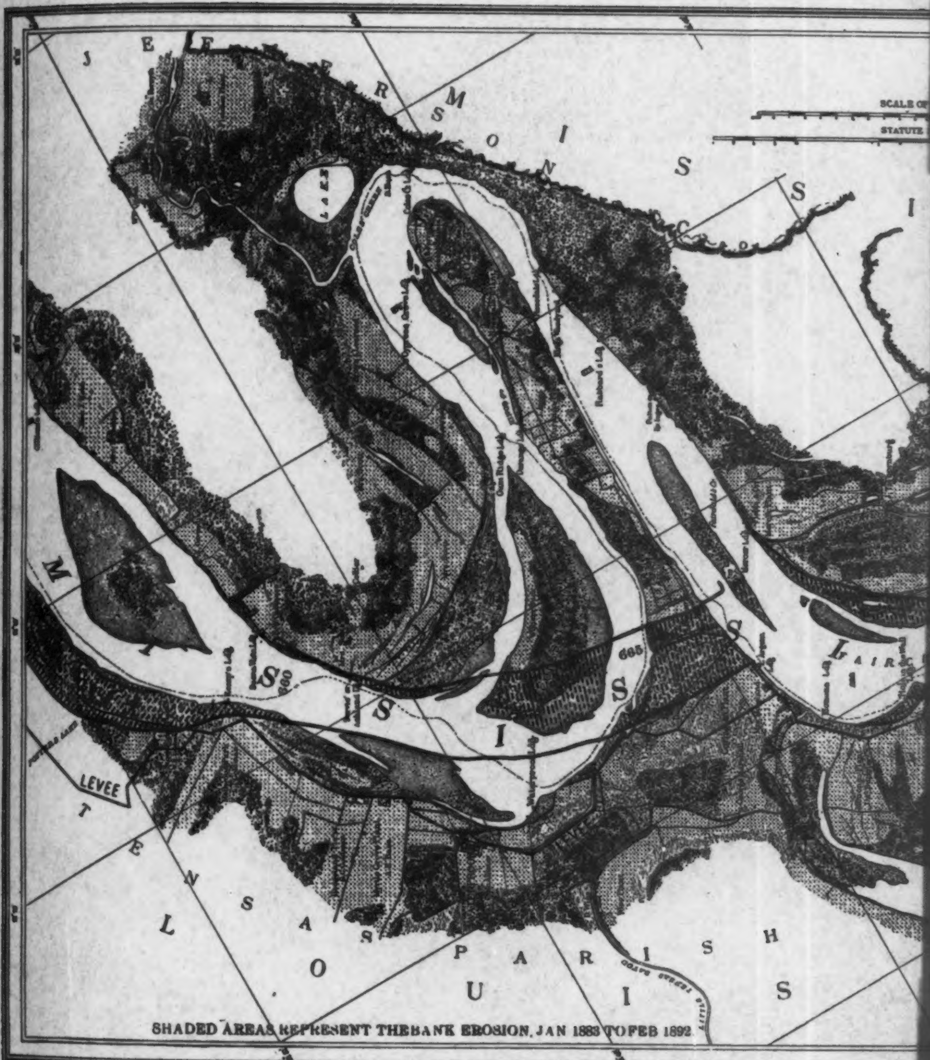
OCKERSON ON EROSION OF RIVER BANKS.


J E F F E R S O N
M I S S I S S I P P I
LAKE
LEVEE
665
660
T E N S A S P A R I S H
L O U I S
SHADED AREAS REPRESENT THE BANK EROSION, JAN 1883 TO FEB 1892.

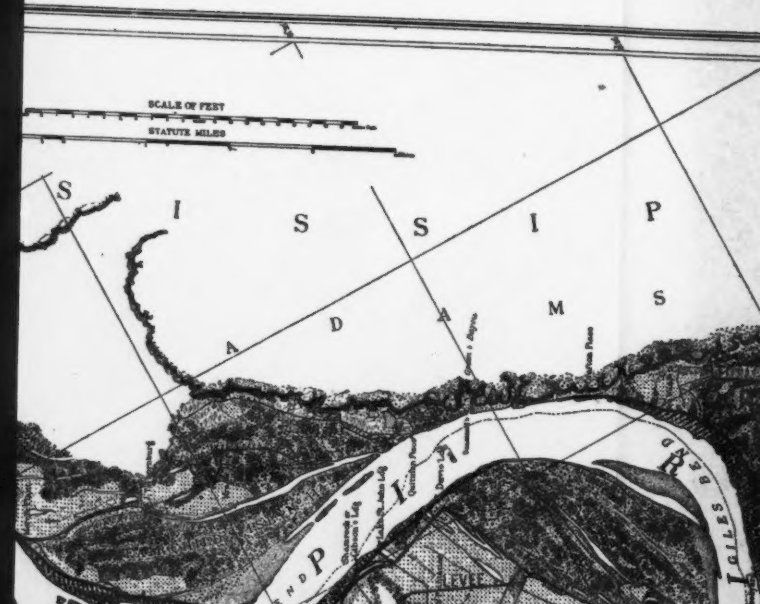

SCALE OF FEET
STATUTE MILES
A D A M S
FAIRCHILDS BEND
GILES BEND
LEVEE
LAKE
LAKE ST JOHN
C O N C O R D I A

PLATE LV.
TRANS. AM. SOC. CIV. ENGRS.
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OCKERSON ON EROSION OF RIVER BANKS.

the river-bed, and large areas settle down, cracking and breaking up as they go, but the trees remain standing. With the accumulated drift they become a menace to flat-boat men and a rendezvous for log hunters, who are always on the lookout for stray logs that come floating down the river.

In November, 1891, a large tract in the City of New Orleans, near the French markets, showed signs of disintegration. Cracks appeared 250 ft. from the river bank and extended 1 600 ft. in length. This whole area gradually settled, and the surface became broken and uneven. The subsidence amounted to from 5 to 10 ft. and then apparently ceased. The railroad tracks were leveled up and the levee repaired, and no further damage has been done. Borings in this vicinity show a stiff clay for a distance of about 50 ft. and a stratum of sand about the same thickness below it.

Tabulation of Data Relating to Erosion.—Table No. 1 shows for the Mississippi River, 1st, the bank eroded ; 2d, the distance in miles from Cairo ; 3d, the length of bank eroded ; 4th, the height of bank above *thalweg;* 5th, annual amount of erosion, area and volume ; 6th, degree of curvature of caving bends ; 7th, percentage of cultivation ; 8th, the character and composition of banks as derived from a low-water examination.

The area of erosion was derived by platting the bank line of the new survey on the detail maps of the old survey, scale 1 to 20 000, and measuring the areas between the lines with a planimeter, each area being measured two or more times.

The annual rate of erosion for each area was derived by dividing the total amount of erosion by the number of years elapsing between the two surveys. In these deductions we are necessarily compelled to assume that the rate of caving has been constant and uniform during the period elapsing between the two surveys. This assumption, while not absolutely true, will answer for purposes of comparison. In many cases, we know the caving has been continuous, if not constant, and in a few cases the conditions have changed from erosion to accretion perhaps more than once.

The average height of the banks was derived from the soundings at known stages and known elevations of the banks, both being shown on the detail maps.

The curvature of the caving banks was derived by drawing the

curve which fitted the general trend of the bend, and then measuring the radius and the angle included between the limiting radii. These curves were sometimes compound and occasionally reversed. The latter are indicated in the tabulation by a minus sign placed before the figures indicating the degrees of the curve. This means that the caving bank is convex to the river.

The column of "percentage of cultivation" shows the relative proportions of cultivated or timbered land which has been eroded.

From these tables a graphical representation was made, giving for each individual caving area the rate of caving per annum for each mile of caving bank (see Plate LVI). In this plate the caving on each bank is shown by triangular-shaped figures in which the base represents the length of caving, and the apex gives the rate of caving in square yards per annum per mile of said caving length. In length, the large squares represent 50 miles, as shown by the figures between the two banks. In area, the large squares represent 40 000 square. That is, if the apex of the triangular figure reaches the line marked 80 000, it shows that this particular area caves at the rate of 80 000 sq. yds. per annum for each mile of its caving length. This explanation applies also to Plate LVII.

An inspection of Plate LVI shows that the maximum rate of erosion lies between the limits of 510 and 660 miles from Cairo. The rate of caving here is far in excess of any other reach, the maximum being at 620 miles below Cairo, where on the left bank in Newtown Bend it reaches 224 000 sq. yds. per annum for each mile of the caving length.

The left bank levee system ends, as shown on Plate LVI, at 575 miles below Cairo, near the lower end of the Yazoo basin, and owing to the proximity of the hills the left bank has no levee from the above point to Bâton Rouge, 835 miles from Cairo. The right bank levee system begins at 425 miles below Cairo, and extends down to 735 miles below Cairo, or a short distance above the mouth of Red River.

It is readily seen, then, that the area of greatest caving coincides with the leveed portion of the river, and this coincidence suggests that there is some intimate relation between the two.

The second era of active levee building on this portion of the river began in 1883, or about the same time that the first survey of the Commission was made; hence the comparisons here made give no clue as to the rate of erosion before the levee period. Coles Point Cut-Off, at

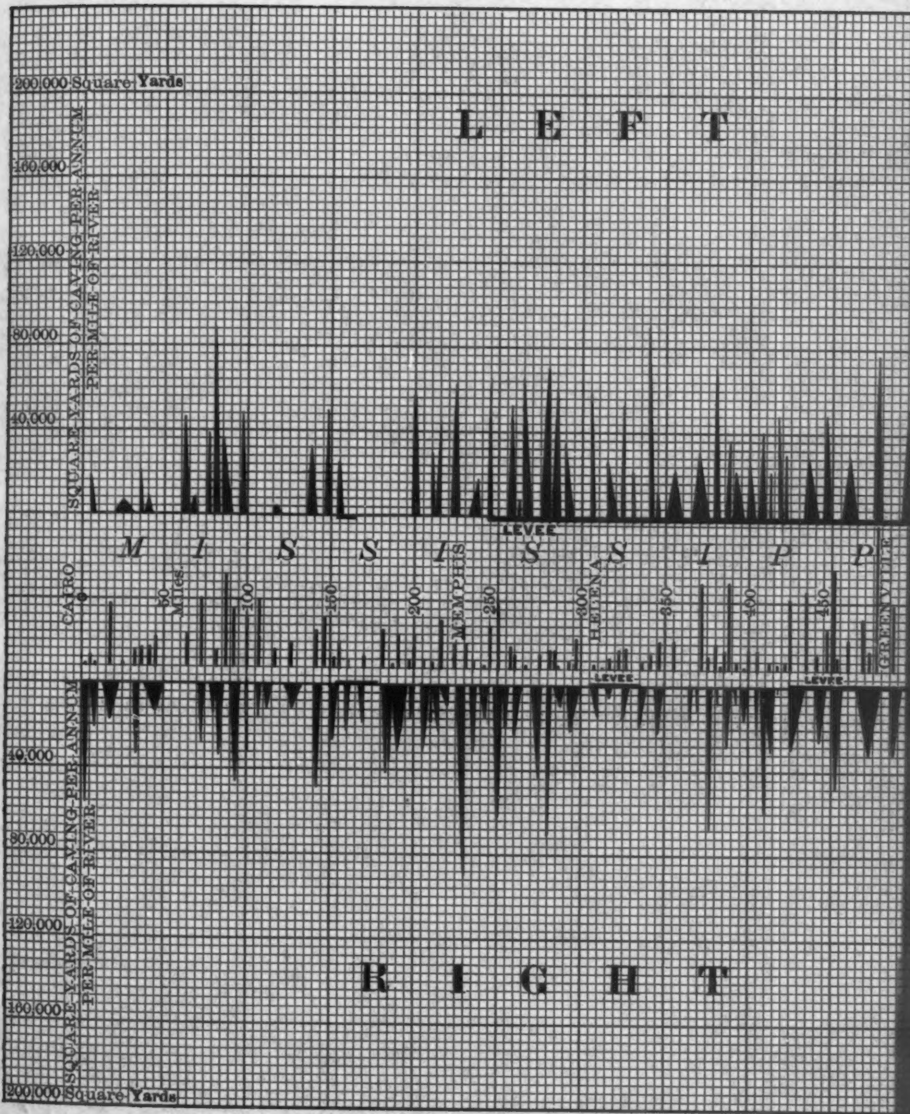
200,000 Square Yards
160,000
120,000
80,000
40,000
SQUARE YARDS OF CAVING PER ANNUM PER MILE OF RIVER
LEFT
LEVEE
MISSISSIPP
CAIRO
50 Miles.
100
150
200
MEMPHIS
250
300
HELENA
350
400
450
GREENVILLE
40,000
80,000
120,000
160,000
200,000 Square Yards
RIGHT

PLATE LV
TRANS. AM. SOC. C
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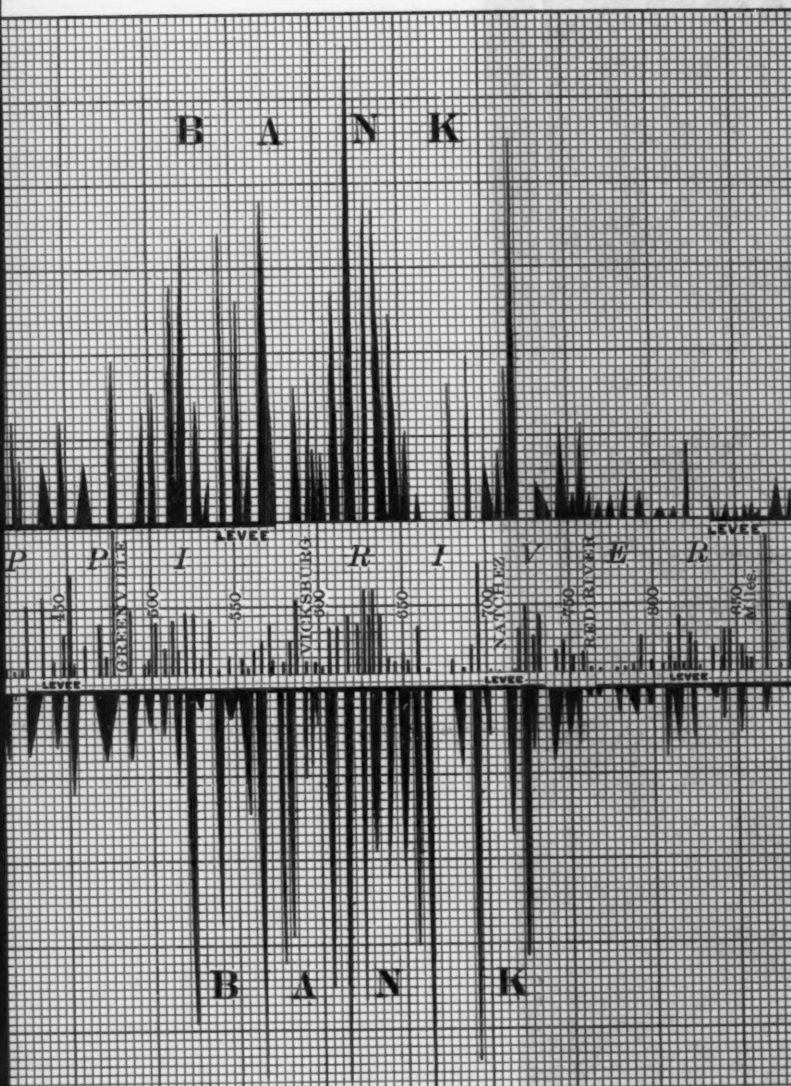
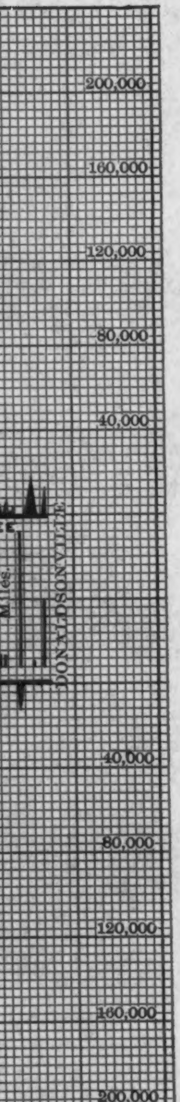
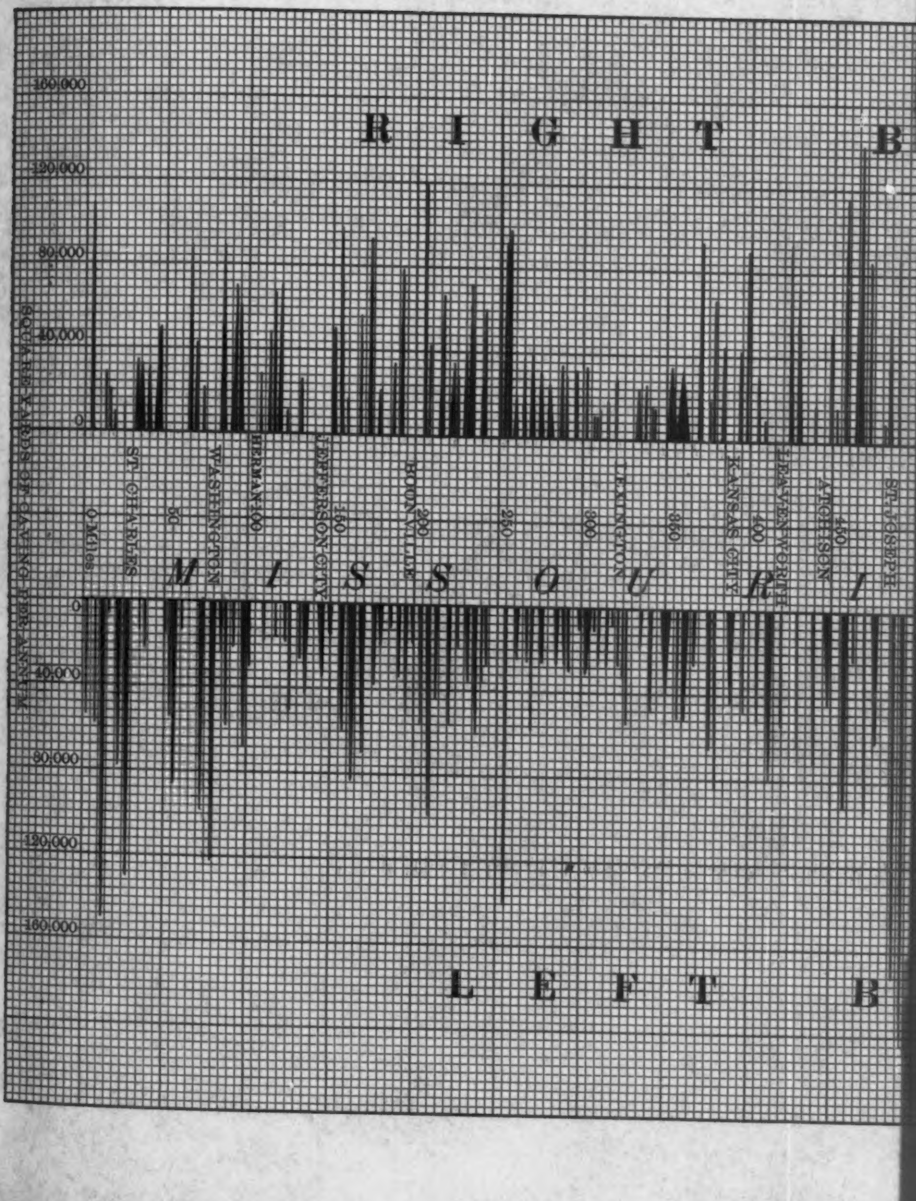
OCKERSON ON EROSION O



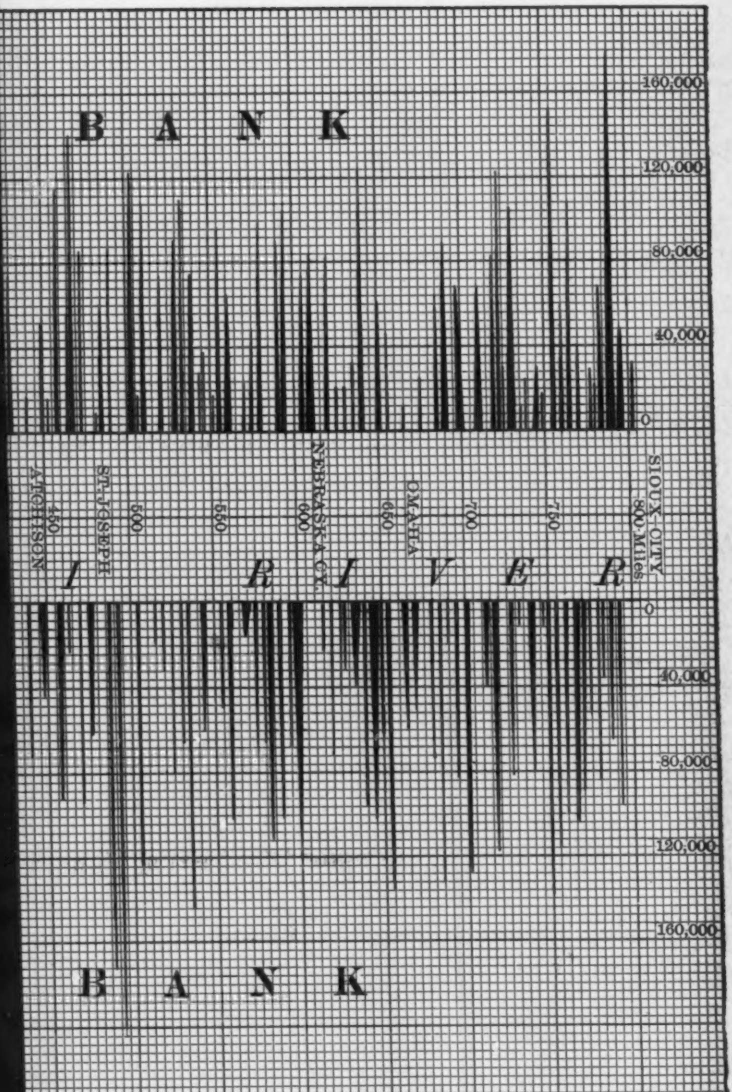
ATE LVI.
SOC. CIV. ENGRS.
XVIII, No. 600.
OSION OF RIVER BANKS.





RIGHT B
LEFT B
M I S S O U R I
SQUARE YARDS OF CAVING PER ANNUM
160,000
120,000
80,000
40,000
0
0 Miles
ST. CHARLES
50
WASHINGTON
HERMAN 100
JEFFERSON CITY
150
BOONVILLE
200
250
300
LEXINGTON
350
KANSAS CITY
400
LEAVENWORTH
ATCHISON
450
ST. JOSEPH

PLATE LVII.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XXVIII, No. 600.
OCKERSON ON EROSION OF RIVER BANKS.



665 miles below Cairo, which occurred in 1884, shortened the distance between Vicksburg and Natchez about 12 miles or 12 per cent. This increase of slope may have a marked influence in bank erosion. Erosion has apparently been active in this region for a much longer period than the levees have been in use, as abundantly shown in the the nine cut-off lakes marking the former bed of the stream—an average of one every 17 miles.

As has been previously stated, active erosion is greatest when the river is within its banks, and consequently not influenced or controlled by the levees. How, then, can the levees affect or influence the amount of bank erosion ?

From Bâton Rouge down, the levees are intact on both sides of the river and stand on its immediate banks, which are generally 100 ft. or more in height; yet caving is comparatively light. A very marked diminution of caving begins at Red River and diminishes gradually as we approach the Gulf, although the height of the banks above the bed of the river is very much greater, except near the Head of Passes.

From Cairo down to 510 miles below, the erosion is tolerably uniform. There are, of course, some areas of considerable erosion, but they are all far less in amount than in the stretch below it, previously considered. Here we find 10 cut-off lakes, or an average of one for every 51 miles of river.

It is more than probable that the locality of excessive erosion is moving slowly. Perhaps the work of adjustment between the forces of slope and momentum and the section of river-bed and stability of banks has been completed, and the proper equilibrium established at the lower end of the river, and these conditions of equilibrium are gradually working up stream, preceded by an area of excessive activity and leaving behind an ideal completed river. Then we should expect to find, in the course of time, that the area of excessive erosion had moved up stream.

Perhaps the forces which have been active in building up sand bars and islands, which divide the channel and obstruct navigation, gather momentum as they go, reaching their climax where we now find the area of excessive erosion. Then we should expect to find this area of activity moving gradually down stream, and extending its baleful effects towards the Gulf.

Profit Island, 815 miles from Cairo, is the farthest down stream of

all the islands. It held the same position when Captain Pitman passed it 125 years ago. There are no obstructing sand bars or islands below it, except at the Head of the Passes, 250 miles distant. If they move down stream bodily, why do they not push farther down? Will they ever reach down to the Gulf of Mexico? These are interesting questions not so easily answered.

An attempt has been made to trace some relation between the amount of caving and the curvature of the bends. In Plate LVI the curvature is shown graphically by lines drawn between the two river banks. The relative lengths of these lines show approximately the relative curvature of the bends, as the lines express the ratio of the curve and its chord. This is given more accurately in column 6 of Table No. 1. A casual inspection shows that excessive curvature and excessive erosion are rarely coincident. The Greenville Bends are examples of great curvature, but the erosion is much greater in bends of less curvature.

The Mississippi River, below Cairo, is characterized by a succession of long sweeping bends, and the straight reaches separating them are usually short. The channel line lies along one bank for a distance and then crosses over gradually to the other bank. The distance between Cairo and the Gulf, measured along the channel line, is 1 063 miles. The air line distance is 543 miles.

If the curvature could be materially increased, so that the strength of the banks and the energy of the flowing water should finally be in equilibrium; perhaps a curve of stability would be found where erosion from impinging currents would practically cease, and the erosion due to saturation and undermining would be materially diminished. As the composition of the banks differs in different localities, such an adjustment as noted would be difficult to make.

It has been thought that bank erosion has been hastened by cultivation of the adjacent lands, which has removed the roots of trees that were supposed to hold the particles of earth together. If the caving process was one of gradual disintegration, then this might be true. But it has been previously shown that undermining is the most active agent, and it is effective far below the influence of roots.

If timber has an appreciable effect on the stability of the banks and tends to preserve them, then, in long bends where there are strips of timber and cultivation alternating, the banks would be found more

deeply eroded along the cultivated portion, and they would necessarily become irregular in outline. This is not found to be the case. A careful investigation of all of the bends fails to reveal any such irregularity, and it is reasonable to conclude that the character of vegetation has little or nothing to do with the amount of erosion. The percentage of cultivation in each eroded area is given in column 7, Table No. 1.

A careful study of Plates LI to LV will tend to verify these statements. On Plate LI, the New Madrid Bend, where the river runs due north for several miles, is a conspicuous feature. Note also the large areas sliced out of the left bank in the wide, straight reach below New Madrid. The New Madrid Bend is unique in being the only one on the lower river where the land on both sides is above ordinary floods.

Plate LII shows the great changes that have occurred in the vicinity of Walnut Bend and Commerce. Opposite Commerce a double change took place during the interval elapsing between the two surveys. When the first survey was made, very active caving was going on on the right bank. This erosion ceased, and an accretion some 2 000 ft. wide and 5 miles long was made. This is as high as the surrounding land, and is now cultivated. At the present time erosion has begun to tear it down again.

Plate LIII shows the exceedingly crooked portion of the river near Greenville, Miss., which by some are termed the "Ox Bows." Here it will be seen that the caving in all of these bends is continuous, but not so great in amount as in other reaches.

Plate LIV shows the region of greatest activity at present, and also the cut-off which left Vicksburg quite a distance from the present channel. The inclination of the river to follow its own lines is here shown. During the late war General Grant attempted to make a cut-off several miles above Vicksburg, so that his fleet could pass the Confederate batteries beyond the reach of their shot and shell. The canal was dug wide and deep, and considerable water flowed through it, but the river continued on around the old bend. Thirteen years later, a cut-off was suddenly made, without any artificial aid, at a point about two miles below "Grant's Canal."

Plate LV shows the river in the vicinity of Coles Point Cut-Off, which occurred in May, 1884, and none have been made on the lower river since that date. Attention has been previously called to the stability of this point for a great many years, in spite of efforts to cut

TABLE No. 1.

MISSISSIPPI RIVER.—BANK EROSION FROM CAIRO, ILLS., TO DONALDSONVILLE, LA., A DISTANCE OF 885 MILES.

Bank.	Distance from Cairo. Miles.	Length. Yards.	Average depth. Yards.	Caving per Annum.		Curvature.		Percent. of Cultivation.	Character of Banks.
				Area, 1 000 sq. yds.	Volume, 1 000 cu. yds.	Radius. Miles.	Degrees.		
Right	1.5	7 000	13.5	178	2 397	2.0	50	10	Sand.
Left.........	0.6	5 000	8.0	106	844	....	....	0	Sand.
Left.........	4.5	6 140	13.0	51	667	3.75	55	0	Sand and clay.
Right	8.3	4 280	20.2	42	848	5.5	25	30	Sand and clay.
Right	17.0	14 200	20.3	131	2 659	2.25	130	30	Sand and silt.
Left.........	23.0	8 130	19.0	21	392	....	....	100	Clay and sand. Bluffs.
Right	32.0	7 280	20.0	145	2 908	2.75	80	10	Clay and sand.
Right	37.8	4 170	17.5	44	765	....	....	0	Clay and sand.
Left.........	35.0	3 210	29.5	37	1 091	....	....	0	Clay and sand.
Left.........	39.2	11 490	19.6	35	692	5.00	50	90	Clay and sand. Bluffs.
Right	41.0	3 740	12.5	14	176	....	....	0	Sand.
Right	47.2	9 310	21.7	65	1 408	2.50	110	70	Sand and clay.
Left.........	43.5	1 500	12.7	3	34	....	....	0	Sand.
Left.........	52.4	4 920	14.5	15	224	....	....	10	Considerable clay with sand.
Right	56.4	2 140	14.6	6	88	....	....	50	Mostly sand.
Left.........	61.2	7 280	24.7	137	3 387	2.75	80	100	Largely sand with little clay.
Left.........	67.8	3 490	14.0	21	287	....	....	0	" " "
Right	72.0	10 120	22.8	128	2 929	2.25	140	100	" " "
Left.........	75.8	5 140	20.1	107	2 143	4.75	40	100	" " "
Right	78.5	5 350	10.4	58	601	....	....	20	" " "
Left.........	79.6	5 050	14.4	356	5 128	2.75	60	50	Chiefly find sand.
Right	83.0	5 860	23.8	149	3 542	....	....	100	Sandy.
Left...... ..	86.0	11 730	18.0	227	4 079	1.25 5.	120 45	20	Sandy.
Right	93.0	9 840	24.1	231	5 563	1.25 6.	130 20	10	Sandy.
Left.........	98.8	17 590	18.5	141	2 602	6. 1.25 4.	20 70 80	20	Sandy.
Right	106.4	7 020	26.2	145	3 805	1.5	150	90	Sandy.
Right	110.7	5 350	17.4	48	842	6.	30	90	Sandy.

Left........	116.3	7 700	17.7	12	1 211	3.25	80	0	In this bend blue clay predominates.
Right	120.4	4 490	11.3	83	938	....	....	0	Sand.
Right	126.0	12 050	19.7	156	3 080	4.0	80	30	Layers of sand separated by seams of clay.
Left........	129.5	2 350	15.5	6	89	....	....	0	Sand.
Right	131.8	1 500	22.0	6	143	7.0	10	100	More clay than sand.
Left........	137.0	9 200	23.2	154	3 570	1.5 5.5	100 20	30	Sand and seams of clay.
Right	142.6	9 120	22.4	213	4 765	1.0 6.0 2.0	70 12 60	30	Sand and seams of clay.
Left........	146.0	4 960	18.5	75	1 380	2.0	70	0	Sand and seams of clay.
Left........	148.3	6 850	16.5	168	2 769	6.0	25	0	Sand and seams of clay.
Right	151.3	5 780	19.2	118	2 262	2.0	90	0	Sand and seams of clay.
Left........	154.8	6 630	19.7	102	2 013	2.25	80	20	Sand and seams of clay.
Right	160.0	3 970	16.2	62	1 010	2.0	65	0	Sand.
Right	164.0	5 990	12.5	70	875	4.0	55	0	Chiefly fine sand.
Right	169.0	4 710	19.7	75	1 472	10.0	15	10	Sand and layers of clay.
Left........	173.7	1 500	19.3	3	62	....	....	0	Sand and gravel. Bluffs.
Right	175.7	1 610	15.7	3	48	....	....	100	Sand and clay.
Right	176.5	4 490	13.7	125	1 714	2.5	40	50	Sand and clay.
Right	182.5	5 350	17.7	112	1 989	1.5	—100	100	Chiefly sand with seams of clay.
Left........	184.8	3 380	24.0	14	342	....	....	100	Clay from bluff. Bluffs.
Right	189.0	4 090	10.7	57	615	....	....	100	
Right	191.4	19 260	19 8	290	5 739	2.5	185	80	Sand with thick layers of clay.
Left........	195.0	3 000	13.7	47	646	....	....	100	Sand and clay.
Right	198.0	4 280	16.3	46	754	....	....	100	Sand and clay.
Left........	201.5	10 120	16.2	230	3 723	2.5	100	50	Sand with layers of clay.
Right	205.0	5 290	20.8	125	2 609	2.75	60	20	Sand and clay.
Right	208.8	5 140	21.3	43	910	....	....	0	Sand and clay.
Left........	211.5	3 100	24.0	61	1 456	7.0	10	100	Sand and clay.
Right	213.5	4 070	4.5	108	485	....	....	0	Mostly sand and silt.
Island	213.0	7 920	13.3	125	1 666	6.5	18	80	Mostly sand and silt.
Left........	213.0	3 210	11.9	55	652	....	....	50	Sand with clay.
Island......	215.0	2 250	12.3	23	278	....	....	50	Sand with clay.
Right	218.2	5 560	20.6	38	950	2.0	100	0	Sand with clay.
Right	221.0	680	15.0	1	20	....	....	100	Sand with clay.
Left........	225.0	11 660	17.2	318	5 456	1.75	90 00	50	Clay with sand and silt.
Right	229 0	8 900	22.1	361	7 981	3.0	50	0	Clay with sand and silt.
Left........	235.0	11 980	15.6	118	1 837	1.25	90	70	Clay from bluffs. Bluffs.
Island......	234.5	4 750	13.5	86	1 167	....	....	10	Sand and clay.
Island......	238.0	2 140	13.3	12	165	....	....	0	Sand and clay.
Right	243.0	7 020	15.0	70	1 050	....	....	100	Sand and clay.
Left........	244.5	7 960	15.7	188	2 945	2.50	110	70	Largely sand with little clay.

TABLE No. 1—(*Continued*).

Bank.	Distance from Cairo. Miles.	Length. Yards.	Average depth. Yards.	Caving per Annum.		Curvature.		Percent. of Cultivation.	Character of Banks.
				Area, 1 000 sq. yds.	Volume, 1 000 cu. yds.	Radius. Miles.	Degree.		
Right	250.6	11 660	19.8	307	6 082	2.50	120	20	Mostly clay with some sand.
Left........	257.0	11 560	15.6	259	4 050	4.0	70	80	Sand with layers of clay.
Left........	261.0	2 890	6.0	17	104	....	....	90	Sand.
Right	262.0	6 310	11.9	106	1 266	6.0	—50	30	Sand and clay.
Left........	267.0	7 360	10.2	321	3 270	....	....	0	Sand and silt.
Right	269.0	3 850	11.0	25	270	....	....	0	Sandy.
Right	274.5	9 420	11.1	205	2 280	4.0	—45	50	Sand with layers of clay.
Left........	278.2	6 630	20.0	281	5 614	1.75	110	10	Sand and clay.
Right	280.5	1 710	17.8	100	1 780	2.0	20	0	Sandy.
Right	281.5	5 160	18.0	218	3 931	1.50	90	80	Sand and clay.
Left........	284.5	6 030	12.3	232	2 855	4.0	35	0	Sand and silt.
Right	285.8	1 600	24.3	11	272	....	....	0	Sand and clay.
Left........	291.4	6 030	20.3	144	2 920	3.50	90	20	Four feet of blue clay at low-water line. Sand above.
Right	295.5	8 600	18.2	117	2 124	2.0	90	0	Low water, strata of blue clay with cypress stumps.
Left........	304.0	5 780	23.4	161	3 757	4.0	38	30	Sand and silt.
Right	309.0	8 770	21.8	70	1 532	7.0	35	100	Layers of clay and sand. Bluffs ¾ miles back.
Left........	315 0	3 850	25.3	32	803	6.0	20	100	Layers of clay and sand.
Left........	318.5	2 460	13.0	14	181	....	....	100	Layers of clay and sand.
Left........	319.5	640	5.3	4	19	....	....	100	Sand and fine gravel.
Right	319.0	3 850	20.7	24	494	7.0	18	100	Apparently a black alluvium.
Left........	322.7	5 140	23.0	211	4 864	3.0	55	20	Sand and clay.
Right	327.0	8 020	22.2	79	1 760	2.5	100	0	Clay and sand. Caves in large blocks with trees erect.
Left........	331.0	3 550	22.4	29	655	5.	25	0	Sand and clay.
Left........	332.0	4 490	21.5	75	1 620	4.25	25	0	Sand and silt.
Right	336.5	8 800	15.7	108	1 650	4.0	50	20	Sand.
Left........	341.0	8 350	20.3	252	5 036	3.0	80	30	Sand.
Right	344.0	4 920	26.7	72	1 798	1.50	110	0	Sand.
Right..	348 5	9 720	23.1	88	1 992	2 0	90	20	Sand and clay.
Left........	353.0	11 430	23.9	194	4 631	2.0	200	0	Sand and clay.
Left........	359.0	5 350	18.6	21	397	10.	18	30	Sandy.

Right.......	360.3	730	14.0	1	16	....	....	0	Sand and clay.
Island......	362.3	3 750	11.3	71	805	....	....	0	Sand and clay.
Right.......	362.5	4 120	26.4	46	1 204	2.0	60	0	Sand and clay.
Right.......	367.5	4 280	20.9	36	762	....	....	0	Sand and clay.
Left........	370.8	13 700	23.1	268	6 260	2.5	155	20	Sand and clay.
Right.......	376.0	6 420	26.8	205	5 496	3.25	63	0	Largely sand.
Left........	380.0	6 850	28.6	209	5 978	1.5	150	0	Sand and clay.
Right.......	381.5	1 600	9.3	8	80	....	....	0	Sand.
Left........	382.7	4 070	19.0	106	2 093	....	00	50	Sand.
Right.......	386.5	1 040	25.7	146	3 787	1.75	163	0	Clay layers, separated by sand.
Right.......	391.5	4 070	10.7	18	191	....	....	0	Sand.
Left........	392.0	8 820	24.8	116	2 874	2.75	95	30	Sand and clay.
Right.......	396.5	6 060	26.1	87	2 282	....	00	0	Sand and clay.
Left........	399.5	5 630	25.0	208	5 211	2.0	90	30	Sand and clay.
Right.......	403.5	6 630	13.6	91	1 240	5.0	—35	0	Sandy.
Left........	406.0	7 060	23.5	207	4 907	2.25	—60	0	Sandy.
Right.......	409.3	4 960	32.7	120	3 907	1.5	110	0	Sand and clay.
Left........	411.8	2 670	11.7	44	511	....	....	0	Sand.
Right.......	413.8	6 420	13.5	90	1 220	1.5	—110	50	Clay with sand.
Left........	416.0	4 280	18.0	113	2 036	3.0	50	0	Sandy.
Right.......	418.8	1 370	17.4	6	102	....	....	0	Sandy.
Left........	418.2	7 700	31.7	145	4 612	4.0	34	0	Sandy.
Left........	422.3	5 460	19.8	90	1 776	....	....	100	Sand and clay.
Right.......	427.7	17 850	30.8	260	7 995	1.25 3.0 1.0	90 120 160	50	Layers of clay and sand.
Left........	436.0	12 070	22.8	175	404	....	00	100	Sand and clay.
Right.......	441.5	9 690	29.4	133	3 924	3.0	110	0	Clay and sand.
Left........	447.0	11 310	24.9	338	8 541	1.75 1.50 1.5	130 —80 150	0	Sand with layers of clay.
Right.......	452.0	10 800	29.7	283	8 398	....	00	0	Sand with layers of clay.
Left........	460.5	17 980	26.3	280	7 318	2.3	180	0	Sand with layers of clay.
Right.......	469.0	20 440	25.0	446	11 150	6. 1.25 3.25	25 130 120	80	Sand with layers of clay.
Left........	477.5	13 800	26.2	455	11 919	2.5 1.5	60 100	30	Sand with layers of clay.
Right.......	487.5	14 770	20.4	215	4 188	2.0	140	10	Sand with layers of clay.
Left........	494.3	8 670	20.1	206	4 138	3.0	50	0	Sandy.
Right.......	497.4	4 020	23.0	75	1 736	4.0	—50	0	Sandy.
Left........	500.0	6 200	26.8	308	8 261	2.75	105	60	Chiefly sand and silt.
Left........	502.7	3 210	15.0	80	1 200			0	Chiefly sand and silt.
Right.......	503.8	3 890	23.1	84	1 934	3.5	50	0	Chiefly sand and silt.
Right.......	509.5	9 200	28.6	241	6 903	1.5	110	50	Sand and clay.

TABLE No. 1—(*Continued*).

Bank.	Distance from Cairo. Miles.	Length. Yards.	Average depth. Yards.	Caving per Annum.		Curvature.		Percent. of Cultivation.	Character of Banks.
				Area, 1 000 sq. yds.	Volume, 1 000 cu. yds.	Radius. Miles.	Degree.		
Left	513.3	8 350	25.6	660	16 916	2.75	115	50	Sand and silt.
Right	515.5	5 890	20.3	213	4 329	7.0	—30	60	Sand.
Left	519.5	5 990	28.0	532	15 054	....	00	20	Sand.
Right	524.5	11 020	30.9	636	19 856	1.75	120	10	Sand with layers of clay.
Left	528.5	6 030	10.7	219	2 348	2.75	70	30	Sand and clay.
Right	530.0	6 100	16.4	34	251	6.0	10	100	Sand and clay.
Left	533.4	10 490	9.9	98	963	6.0 / 1.0	30 / 90	50	Sand and clay.
Right	541.8	16 780	21.4	560	11 990	3.0	80	100	Sand and clay.
Left	543.2	4 920	17.1	409	6 987	....	00	100	Chiefly sand and silt
Right	547.8	6 550	25.1	92	2 303	4. / 1.5	30 / 90	0	Chiefly sand and silt.
Left	551.7	2 780	21.6	272	5 884	1.75	60	60	Chiefly sand and silt.
Left	553.2	6 630	28.9	420	12 136	1.75	90	100	Sand.
Right	555.5	7 700	9.7	346	3 356	....	00	0	Sand.
Island	558.5	3 100	19.8	131	2 596	....	....	0	Sand.
Left	558.5	7 700	21.1	152	3 202	2.0	—90	100	Sand.
Right	565.2	10 190	23.1	914	21 124	2.75	110	100	Soil darker than usual, with considerable clay.
Left	570.4	17 120	20.7	1 206	24 976	1.65 / 3.75	150 / 70	80	Sand and clay.
Right	576.0	6 850	29.7	386	11 527	3.75	50	20	Low-water strata heavy clay; caves in large areas.
Island	577.7	1 710	25.7	77	1 978	....	....	0	Sand.
Right	582.3	15 190	22.1	578	12 773	6. / 2.25	30 / 80	100	Hard clay points. Upper 12 ft. brown silt.
Left	585.7	12 070	17.7	446	7 889	1.0	85	0	Clay and sand.
Right	589.7	4 940	25.0	121	3 036	6.5	18	100	Clay and sand.
Left	592.1	5 140	20.2	131	2 639	2.0	—70	0	Sand and silt.
Right	594.5	5 520	29.0	151	4 360	2.0	60	60	Sand and clay.
Left	597.6	4 070	12.0	63	758	....	....	100	Sand and silt.
Right	598.1	3 850	26.7	33	890	....	....	100	Sand and clay.
Left	601.5	4 840	30.3	185	5 605	2.25	70	70	Sand and clay. Bluffs.
Right	604.8	10 230	26.8	718	19 146	2.0	130	70	Sandy silt. Drops down in blocks 200 ft. wide.

Left........	610.0	12 280	21.8	646	14 079	3.75	100	70	Low-water strata clay with dark silt and sand above.
Right	615.0	10 910	20.8	737	15 322	3.35	85	30	Cypress stumps in yellow silt and sand.
Left........	620.2	12 200	21.7	901	19 437	1.50	150	50	Layer of clay at low water, brown silt and sand above.
Right	624.3	8 240	26.4	547	14 448	1.25 2.25	90 40	40	Wide strata of dark clay at low water, sandy above.
Left........	628.3	5 990	29.2	416	12 124	1.50	140	0	Dark sand and silt.
Right	632.2	11 860	25.1	463	17 704	1.25 4.25	128 40	10	Lower strata clay with cypress stumps, dark silt and sand above.
Left........	637.0	8 650	22.4	547	12 256	1.0 5.75	100 25	10	Sand and clay.
Right	641.6	11 130	27.8	606	17 913	3.5	50	50	Sand and clay.
Left........	647.3	13 700	20.5	295	6 056	4.0 2.0	40 —70	70	Sand and clay.
Right	650.5	9 720	31.7	401	12 698	3.0	80	30	Largely tough clay.
Left........	653.6	5 780	38.0	130	4 944	2.75	60	50	Sand and clay.
Right	658.0	10 060	24.4	604	14 738	1.75	150	80	Very sandy.
Left........	661.0	4 150	19.6	31	603	....	....	60	Very sandy.
Left........	664.0	1 390	17.0	60	1 016	5.25	—20	0	Sand and clay.
Cut-Off.....	665.4	1 930	24.7	411	9 047	5.25	20	100	Sand and clay.
Left........	681.3	5 780	10.7	167	1 728	3.50	50	30	Sand and silt.
Right	683.0	10 560	31.5	178	5 607	4.0 3.0	40 —40	10	Sand and silt. Bluffs.
Left........	688.5	9 970	31.5	377	11 866	2.0 6.0	90 20	40	Sand and clay.
Right	693.0	9 120	33.8	862	29 120	1.5	200	70	Sand and silt.
Right	697.2	1 930	32.3	72	1 229	1.0	50	80	Sand and silt.
Right	700.0	1 160	14.6	5	77	....	....	0	Sand and silt.
Left........	700.3	4 920	27.3	17	480	1.75	70	100	Clay bluffs.
Left	703.8	1 500	17.3	5	84	....	....	100	Clay and silt.
Right	707.4	7 770	18.8	141	2 653	5.75	40	60	Sandy.
Right	702.2	2 200	20.0	9	185	....	....	100	Sand and clay.
Left........	711.8	9 650	14.4	363	5 224	4.0	65	0	Sand and clay.
Right	714.8	4 880	24.8	337	8 357	7.0	22	30	Clay at low water, yellow silt above.
Left........	718.3	10 490	30.3	411	12 458	1.5 5.0	65 50	30	Upper strata light colored silt, growing darker below. Bluffs.
Right	722.0	6 680	21.8	511	11 086	1.0	190	70	Loose yellow sand.
Left........	724.6	4 240	14.3	97	1 379	1.50	90	0	Sand.
Right	726.2	4 960	36.2	117	4 227	2.0	90	60	Sand.
Left........	732.7	18 450	27.1	176	4 746	5.25 3.0	50 80	100	Dark clay, with cypress stumps.
Right	740.0	10 020	36.3	235	8 500	1.50 3.50	110 40	30	Yellow clay and silt, with points of dark clay.

TABLE No. 1—(*Continued*).

Bank.	Distance from Cairo Miles.	Length. Yards.	Average depth. Yards.	Caving per Annum.		Curvature.		Percent. of Cultivation.	Character of Banks.
				Area. 1 000 sq. yds.	Volume, 1 000 cu. yds.	Radius. Miles.	Degree.		
Left........	740.8	1 500	15.0	26	382	....	....	0	Sandy.
Left........	745.8	10 120	26.9	273	7 316	2.75	100	30	Sand and clay.
Right	749.6	5 220	31.4	110	3 449	6.0	30	20	Sand.
Left........	752.0	3 770	28.9	43	1 231	3.0	60	0	Sand and clay.
Right	752.5	1 030	7.3	4	29	....	....	0	Sandy.
Right	754.6	2 350	40.9	71	2 891	2.5	55	10	Sandy.
Left........	756.8	4 540	44.0	138	6 074	2.0	90	100	Clay and sand. Bluffs.
Left........	761.3	3 470	8.0	26	212	7.0	20	100	Sandy.
Right	761.5	8 240	26.0	22	571	6.0	30	0	Silt and sand.
Right	764.4	1 070	10.6	7	76	2.5 6.0	40 20	0	Silt and sand.
Left........	767.6	4 490	6.3	20	127	2.5	80	0	Silt and sand.
Right	768.6	13 100	32.2	59	1 911	5.0	50	20	Sand and clay.
Leit........	777 0	5 780	26.6	51	1 365	4.0	80	70	Sand and clay.
Island	779.0	2 400	18.3	8	143	....	....	0	Sand.
Right	780.4	4 710	24.9	34	854	6.	—20	0	Sand and clay.
Left........	783.5	3 980	36.4	56	2 072	2.25	70	0	Sand and clay.
Right	788.2	13 380	42.8	87	3 706	2.75	150	70	Large proportion of clay.
Left........	793.6	5 480	37.8	44	1 686	6.0	30	0	Clay.
Right	796.6	11 130	30.0	41	1 233	7.5	30	90	Sand and clay.
Left........	802.3	8 130	35.2	22	774	8.0	20	0	Sand and clay.
Left........	807.3	2 570	12.0	11	136	1.0	—90	0	Sandy.
Right	807.8	6 160	33.8	92	3 130	1.0	100	0	Sand and clay.
Left........	811.0	2 700	53.0	14	749	....	....	0	Sand and clay.
Right	815.3	9 820	32.0	102	3 263	6.75 1.0	30 90	80	Sand and clay.
Left........	820.6	6 930	34.4	144	4 936	1.75	120	0	Sand.
Right	824.0	4 820	40.1	46	1 813	1.25	90	100	Sand and clay.
Right	828.3	1 880	35.0	5	192	0.5	90	100	Clay.
Right	830.5	2 780	17.0	5	82	....	...	100	Clay.
Right	834.0	8 820	23.2	24	555	....	....	100	Clay and sand.
Left.... ...	836.0	7 810	36.0	19	696	6.75	20	100	Clay and sand.
Right	839.6	430	30.7	2	67	6.75	20	100	Clay and sand.
Right	841.2	5 560	29.9	26	788	1.0	130	100	Clay and sand.
Left........	840.4	750	12.3	2	27	1.0	40	100	Clay and sand.

Left.... ...	841 7	5 890	17.1	29	500	1.0	40	100	Clay.
Right	843.2	2 140	20.7	5	100	....	....	100	Clay.
Left........	849.8	9 840	24.3	16	395	1.0	140	100	Clay and sand.
Right	853.5	19 260	28.0	85	2 381	1.0	80	100	Clay and sand.
Left........	855.0	2 740	10 6	14	153	2.0	40	100	Clay and sand.
Left........	859.5	5 030	25.0	14	344	8.0	15	100	Clay and sand.
Left........	863.2	6 530	33.8	14	466	4.0	30	100	Clay and sand.
Right	868.3	13 740	34 3	68	2 315	1.75	70	100	Clay and sand.
Left........	874.6	9 420	32.9	47	1 557	5.0	40	100	Clay and sand.
Right	878.8	3 000	23.0	15	353	7.	—15	100	Clay and sand.
Left........	881.0	4 580	34.4	26	879	1.75	90	100	Clay and sand.
Right	883.2	5 560	31.8	9	279	0.75	90	100	Clay and sand.
Total.....	....	916 miles.	....	39 016 000 sq.yds.					

	Miles.	Square Yards.
Total caving per annum left bank........	430	18 879 000
Total caving per annum right bank	469	19 193 000
Total caving per annum both banks and islands	916	39 016 000
Total average caving per mile of river per annum........	....	44 186
Total average caving per mile of river per annum right bank........	....	21 735
Total average caving per mile of river per annum left bank........	....	21 391
Total average caving per annum per mile of caving bank, right bank........	....	40 921
Total average caving per annum per mile of caving bank, left bank........	....	43 904

it. But when the disintegration once began, a very short time sufficed to turn the channel across it.

In summing up the totals, we find that in 885 miles of river we have 916 miles of caving banks, including the islands. On the left bank we find 430 miles of caving, or 12 miles less than one-half the length of river considered. On the right bank the caving amounts to 469 miles, or 27 miles more than half the length. It should be borne in mind, however, that the left bank of the river strikes the bluffs at 13 points, and follows them for a total of about 27 miles. The right bank does not strike the bluffs at all, the nearest point being at Helena, where the bluffs are about ½ mile from the river.

The total area of caving per annum is 39 016 000 sq. yds., and the average annual rate of caving per mile of river is 44 186 sq. yds., or a little over 9 acres. The average depth of erosion is about 66 ft., hence the annual volume of erosion per mile of river is 972 092 cu. yds. The total average annual volume of erosion from Cairo to Donaldsonville, as derived from these comparisons, would amount to 10 sq. miles, 84 ft. deep. As before stated, there was quite a large movement which occurred between the dates of the surveys which cannot be identified or measured. The grand total, then, would be a somewhat larger quantity than above specified.

The average annual amount of erosion of the right bank per mile of river is 21 735 sq. yds., and of the left bank, 21 391 sq. yds. The average annual amount of erosion per mile of caving bank is, for the right bank, 40 924 sq. yds., and for the left bank, 43 904 sq. yds.

It very rarely happens that both banks cave in the same locality at the same time, and, as a general rule, it may be accepted as practically true that erosion on one bank is followed by an equivalent accretion on the other. In some cases the resultant of the two is a very large decrease in width, the accretion exceeding the erosion. From the lengths of caving on each bank, given above, it is seen that erosion is practically continuous on one bank or the other for the whole length considered. The eroded areas overlap each other slightly.

The total amount per annum of solid matter passing New Orleans in suspension is computed, from sediment observations, to be about 10 sq. miles, 26.8 ft. deep, or less than one-third of the amount of erosion. The two-thirds and more not accounted for, added to the volume tumbled into the Missouri, goes to build up the bars which obstruct navigation and the points which follow the caving bends by accretions.

The Missouri River.—The data for determining the amount of erosion on the Missouri River was derived from a comparison of the surveys of 1879 and 1890. The reach of river considered extends from the mouth up to Sioux City, a distance of 802 miles. The scale of the maps available was too small to permit of close measurements of areas; still, the results are probably not far from the truth. The results were derived by the methods already explained for the Mississippi River.

The lower 250 miles of the river is comparatively straight, and the long, flowing bends which characterize the Mississippi River and the upper reaches of the Missouri are missing. The right bank follows the bluff for a distance of 221 miles, and the left bank, 50 miles.

An inspection of Plate LVII shows that the erosion is pretty uniformly distributed over the whole length. The caving areas are usually quite short as compared with the Mississippi River. The erosion cuts deep into the bank and comes out abruptly, perhaps to attack the opposite side. In general, the banks are composed of fine sand and silt, which is quite homogeneous. A few localities show thin strata of clay in the sand, and occasionally tough clay of considerable thickness is found.

The most active period of erosion is during falling stages, and the lower portion of the bank is the point of attack. The banks are thus undermined, and, being very friable, crumble rapidly.

It is stated in official reports that "evidences everywhere exist throughout the whole extent of the Missouri Valley that in past ages the river has, with more or less periodic regularity, changed the location of its bed from one bluff to the other, and then back again, moving in this change the whole of the enormous amount of soil that lies between, and this operation is still going on." * * * "In the lakes, swamps and lowlands we have unmistakable evidence that as the river is to-day, so it has been for ages past, its peregrinations limited only by the bluffs that bound the valley in which it runs."

The distance between the bluffs from Omaha to the mouth, 668 miles, averages about 3 miles; a considerable proportion of it is 2 miles or less, and it rarely exceeds 7 miles. As compared with the lower Mississippi River, which has a valley from 20 to 60 miles in width, the former is confined to rather narrow bounds, and the "peregrinations," therefore, are necessarily quite limited.

In the distance of 802 miles of river, the total erosion amounts to 818 miles. On the left bank the length of erosion is 411 miles, or 10 miles more than half the length of river. On the right bank the erosion amounts to 330 miles long, or 71 miles less than half the distance considered.

The average area of caving per annum for the 802 miles is 50 019 000 sq. yds., and the average annual rate per mile of river is 62 338 sq. yds., or about 13 acres.

The average annual erosion per mile of river is, for the right bank, 24 804 sq. yds., and for the left bank, 33 304 sq. yds. The average annual amount of erosion per mile of caving bank is, for the right bank, 65 041 sq. yds., and for the left bank, 60 228 sq. yds.

There is no accurate data available for the height of banks along the Missouri River. Estimated at an average height of 36 ft., would give the annual volume of erosion per mile of river 748 056 cu. yds. The total annual erosion would amount to 10 sq. miles, 58 ft. deep.

In comparing the totals with those of the Mississippi River, it will be seen that the annual area of erosion per mile of river is about 30% less for the latter. The volume of erosion on the Missouri is, however, about 23% less than on the Mississippi for the same distance. The left bank erosion per mile of river exceeds the right bank erosion about 25 per cent. On the Mississippi River the right bank erosion per mile of river exceeds the left bank by less than 2 per cent. A part of these differences is to be attributed to the influence of the bluffs. In the first case, if we simply consider in the comparisons the eroding portions of each bank, then the right bank erosion per mile of eroding bank exceeds the left bank erosion about 8 per cent.

On the Mississippi River, comparing in the same way, the left bank erosion exceeds that of the right bank about 7 per cent. Or, in other words, the erosion in both cases is greatest on the bank which lies nearest the bluffs, but it is, of course, confined to the stretches not controlled by the bluffs, which do not yield to erosion to any great extent.

It is plainly evident that bank erosion is one of the principal factors in the solution of the problem of river improvement and control. If contraction works are built, then erosion becomes active on the opposite bank, and the river soon moves beyond the sphere of influence of such works. If levees are built, they are often quickly destroyed by caving into the river, and new lines must be constructed to restrain the floods. On the other hand, active erosion furnishes abundant material to build up the artificial banks where channel contraction is required.

A flimsy pile dike on the lower Mississippi or Missouri induces enormous deposits in a very short period of time. On the upper Mississippi, above the mouth of the Missouri, this action is very much slower, and quite a long period of time is required to gather deposits sufficient to make the contraction works useful.

TABLE No. 2.

Missouri River Bank Erosion From Mouth to Sioux City, Ia. Distance, 802 Miles.

Bank.	Distance from Mouth. Miles.	Length. Miles.	Caving per Annum. 1 000 Sq. Yds.	Character of Bank.
Left	2.	3.2	182	
Right	5.	1.6	173	
Island	1.7	1.2	194	
Island	5.	1.2	73	
Left	8.	1.3	79	
Left	12.5	3.1	468	
Left	14.2	1.7	5	
Right	14.2	0.6	17	
Right	15.6	0.9	14	
Left	16.1	0.5	3	
Island	16.0	0.5	11	
Island	16.7	0.7	11	
Island	18.2	2.5	90	
Right	18.0	2 7	23	
Left	21.9	4.3	338	
Right	25.6	1.2	28	Clay and sand.
Left	27.6	2.6	341	
Right	32.9	3.8	127	
Left	35.7	1.8	45	
Island	36 8	2.7	90	
Right	37.2	3.2	104	
Left	38.6	1.2	28	
Island	40.5	2.1	42	
Right	41.1	1.9	56	
Island	42.9	0.6	11	
Right	46.7	4.5	222	
Island	47.5	3.5	34	
Left	49.0	2.0	90	
Left	50.7	1.0	17	
Left	53.1	2.5	141	
Right	55.6	0.6	14	
Left	56.2	3.0	262	
Right	61.1	3.4	298	
Left	61.7	2.6	37	
Island	63 9	0.6	25	
Right	63.9	2.8	115	
Island	65.0	0 5	17	
Island	65.6	0 5	23	
Island	66.5	0.4	6	
Right	66.6	2.5	56	
Island	68.2	0.5	14	
Left	72.0	4.7	476	
Right	75.1	1.0	17	
Left	78 9	5.1	625	
Right	79 5	4.0	349	
Island	82.5	1.0	51	
Island	82.7	1.5	76	
Left	83 8	2.5	65	
Left	88.0	4.5	259	
Right	91.8	3.4	239	
Island	92.4	0.8	54	
Left	94.4	2.0	175	
Right	95.0	1.2	76	
Island	95.8	0.7	20	
Island	97.5	3.6	45	
Left	98.0	3.9	127	
Island	101.0	1.8	96	
Left	102.8	4.4	135	
Right	107.5	0.5	14	
Left	110.1	2.6	51	
Right	110.0	2 2	93	
Island	111.7	1.6	70	
Right	112.5	2.1	107	
Island	113.2	1.5	84	

TABLE No. 2—(*Continued*).

Bank.	Distance from Mouth. Miles.	Length. Miles.	Caving per Annum. 1 000 Sq. Yds.	Character of Bank.
Right	116.0	3.0	194	
Left	118.6	0.5	8	
Left	120.0	0.7	17	
Right	120.1	4.7	327	
Island	120.2	1.2	14	
Island	123.1	1.5	70	
Left	123.6	0.3	6	
Right	124 1	0.8	8	
Island	124.8	2.4	34	
Island	124.8	0.4	8	
Left	126.6	2.1	107	
Island	127 2	1.7	158	
Leit	131.8	1.7	45	
Right	132.4	1.7	45	
Island	132.8	1.0	73	
Left	136.5	6.9	287	
Island	136.6	1.4	14	
Island	137.0	0 5	17	Sand and gravel.
Island	139.8	0.8	65	
Left	144.5	5.6	197	
Left	150.6	3.1	425	
Right	151.8	1.2	59	
Right	155.2	1.7	166	
Left	157 0	3.0	180	
Island	159.5	1.5	73	
Right	160.6	1.0	14	
Left	163.7	4.5	375	
Right	166.6	3.1	175	
Left	169.3	3.4	237	
Right	173 1	3.4	321	
Left	176 5	2.0	79	
Island	176 9	1.0	23	
Right	178.6	1.1	23	
Left	179.3	2 6	51	
Right	180 9	1.0	20	
Island	181.5	0.6	39	
Right	182.5	2.6	87	
Left	186.0	0.5	6	
Right	187.7	3.5	273	
Left	189.8	0.8	17	
Left	191.4	0.7	37	
Island	193.5	2.9	68	
Island	195.0	1.0	23	
Leit	194.6	4.2	214	
Island	196 0	0.3	6	Sand.
Leit	199.3	3.4	79	
Left	203.3	2.1	118	
Right	205.2	2.4	[illegible]	
Island	206.4	0.4	[illegible]	
Left	207 4	2.5	[illegible]	
Right	209.7	0.9	37	
Left	209.8	0.8	11	
Left	212.4	2.8	138	
Right	216.4	2.4	163	
Leit	219.8	3.5	197	
Right	220.8	4.8	163	
Right	224.0	1.1	31	
Left	225.2	0 45	8	Silt and fine sand.
Right	228.5	2.1	82	
Right	232.0	2.8	206	
Leit	232.0	4.2	155	
Left	236.0	2.25	121	
Left	237.2	0.8	1	
Right	238.7	2.5	66	
Left	240.0	1.0	37	
Right	241.2	0.9	54	
Left	242.0	2.5	70	
Right	251.0	0.9	137	
Right	252.5	3.0	279	

TABLE No. 2—(*Continued*).

Bank.	Distance from Mouth. Miles.	Length. Miles.	Caving per Annum. 1 000 Sq. Yds.	Character of Bank.
Island..........	253.7	0.6	20	
Left............	254.0	1.25	172	
Right..........	256.7	1.9	186	
Island..........	260.3	0.6	20	
Right	260.7	4.5	79	
Left............	260.7	4 3	113	
Right..........	265.0	3.0	113	
Left............	267.2	2.7	70	
Right..........	268.3	1.0	25	
Right..........	269.7	1.0	56	
Left............	270.0	2.2	132	
Island..........	271.0	1 0	186	
Right..........	274 8	3.7	110	
Left............	276 0	3.4	90	
Island..........	276.9	1.3	155	
Right..........	281.4	4.0	104	
Left............	284.9	3.6	90	
Right..........	287.3	4.2	138	
Left............	289.5	2 6	73	
Right..........	290.5	2.9	84	
Left.	292.3	2.9	99	
Right..........	296.1	2.6	82	
Left............	298.0	2.0	23	
Right..........	302.2	1.0	34	
Left............	303.2	5.5	166	
Left............	308.3	2.2	25	
Right..........	308.8	2.0	20	
Right..........	311.6	1.3	17	
Left............	312.6	2.6	68	
Right..........	313.8	1.5	25	
Left............	315.0	2.0	25	
Island..........	316.0	1.1	79	
Left............	317.2	1.4	37	
Left............	319.1	1.2	51	
Right..........	321.2	2.5	68	
Left............	324.1	1 4	11	
Left............	327.1	1.5	39	
Right	328.5	1.0	37	
Left............	330.3	1.6	51	
Left	331.7	1.8	99	
Right..........	332.4	4.7	113	
Left............	336.0	3.0	48	
Right	338.4	2.5	65	
Left............	342.5	3.7	177	
Right	341.1	1.1	17	
Right..........	343.5	1.0	14	
Right..........	349.8	1.4	45	Sand over-lying boulders.
Left............	350.2	6.4	256	
Right..........	353.4	5.0	169	
Left............	357.0	2.1	110	
Right	361.9	6.2	203	
Left............	362.3	3.6	183	
Island..........	363.9	1.0	20	
Left............	367.4	2.8	79	
Right	372.1	3.1	282	
Right	376.8	0.5	11	
Left............	376.9	2.0	132	
Island.....	377.7	1 0	70	
Right..........	379.2	1.7	113	
Left............	381.4	2.9	242	
Right	383.2	2.2	96	Silt over-lying boulders.
Left............	385.3	1.0	17	
Island..........	386.4	0.6	51	
Left............	389.3	5.6	245	Layers of coarse and fine sand.
Right..........	394.6	2.0	84	
Left............	397.1	2.0	99	
Right..........	399.5	2.0	183	

TABLE No. 2—(*Continued*).

Bank.	Distance from Mouth. Miles.	Length. Miles.	Caving per Annum. 1 000 Sq. Yds.	Character of Bank.
Right....	405.6	2.6	82	
Left.............	406 8	4.6	248	
Left.............	412.6	4.0	383	
Left.............	415.9	1.8	82	Sand.
Left.....	421.2	2.5	135	
Chute...........	425.1	2.9	144	
Right....	426.5	2.6	242	
Left.............	428.5	1.6	104	
Right	429.2	1.1	51	
Right......	431.4	2 8	237	
Left.............	437.1	1.4	99	
Left.............	439.4	1.3	93	
Right............	440.8	1.5	23	
Left.............	444.3	1.3	17	
Left.............	447.8	4.5	206	
Right......	449.9	2.4	115	
Left.............	450.8	1.5	14	
Right	452.7	0.5	8	
Left.............	454.5	3.6	335	
Right....	457.1	3.4	394	
Left.............	464.2	2.5	56	
Right	464.6	1.8	101	
Island...........	465.5	0.4	20	
Right....	467.6	3.3	462	
Left.............	471.3	1.2	113	
Right....	472.6	2.1	183	
Left.............	476.4	4.8	298	
Right....	482.2	3.5	34	
Left.............	484.1	3.0	180	
Left.............	487.9	3 7	639	
Right......	491.2	1 0	87	
Left.............	493.3	3.5	890	
Right....	502.2	4.5	555	
Left.............	504.3	2 6	324	
Right....	507.3	1.0	17	
Right	509.7	2.9	310	
Left.............	511.9	1.5	62	
Left.............	515.7	1.2	23	
Left.............	518.9	3.1	99	
Right....	521.2	2.5	186	
Left.............	524.7	1.8	146	
Right......	528.7	4.2	377	
Left.............	531.6	1.7	113	Sand.
Right......	533.8	2.5	276	
Left.............	536.6	3.2	467	
Right	539.2	3 9	293	
Left.............	544.1	3.1	186	Sand and clay.
Right....	544.9	1.0	28	
Right	546.8	0.8	31	
Island...........	547.6	0.5	31	
Island...........	548.5	0.5	17	
Left.............	550.1	2.4	197	
Right....	551.9	2.7	37	Sand and clay.
Left.............	554.7	1.5	76	
Right....	556.5	3 0	298	
Left.............	560.5	2.4	245	
Island...........	560.9	0.7	96	
Right	562.2	5.4	338	
Left.............	568.0	5.5	93	
Island...........	569.0	1.4	23	
Right	569.1	1.8	42	
Right	573.5	2 6	135	
Island...........	575.5	1.1	62	
Left.............	576.8	3.8	270	
Right......	578.2	2.6	259	
Left.............	580.0	1.6	107	
Island...........	582.2	0.8	28	
Left.............	583.6	4.7	527	

TABLE No. 2—(*Continued*).

Bank.	Distance from Mouth. Miles.	Length. Miles.	Caving per Annum. 1 000 Sq. Yds.	Character of Bank.
Chute	584.0	4.5	118	
Island	584.2	1.7	25	
Left	588.1	1.5	132	
Right	590.0	1.7	155	
Left	591.7	1.8	200	
Right	595.1	3.4	355	
Left	595.1	2.5	144	
Island	597.2	1.6	113	
Left	601.5	5.8	721	
Right	605.5	3.0	217	
Right	610.5	4.0	332	Sand.
Island	615.2	0.5	17	
Left	615.3	0.6	14	
Left	618.4	2.5	183	
Right	620.4	3.3	259	
Right	625.2	0.3	6	
Left	626.1	3.1	138	
Left	628.2	1.8	59	
Island	628.7	0.7	23	
Right	631.0	0.3	6	
Island	631.0	0.4	11	
Left	635.6	5 7	231	
Right	635.9	0.9	28	Sand.
Left	640 3	1.8	180	
Right	642.3	2.1	259	
Island	643 6	0.2	23	
Left	646.3	5.1	524	
Right	649.6	2 2	141	
Right	651.9	2.2	110	
Left	654.6	3.6	498	
Right	655.9	1.2	54	
Right	663.3	1.5	17	
Left	665.3	3.9	234	Sand and clay.
Left	670 1	1.6	84	
Left	672.8	3.0	141	
Right	677.2	3.4	82	
Left	680.6	3.0	222	
Right	684.4	1.8	115	
Left	687.8	4.3	487	
Right	690.3	4.4	372	
Left	692.3	1.8	37	
Left	695.3	3.5	287	
Right	698.3	5.7	391	Fine Sand.
Left	702.3	3.9	515	
Right	710.2	4.0	270	
Left	713.7	3.6	161	
Right	718.4	2.3	186	
Left	718.9	6.5	772	
Right	723 6	2.8	346	
Island	725.2	0.5	20	
Right	725.4	0.9	28	
Left	727.0	3.4	282	
Right	730.7	4.6	479	
Left	733 5	0.5	6	
Left	735.8	1.6	34	
Right	736.4	1.5	17	
Right	738.5	0 7	17	
Left	741.4	5.3	431	
Right	745.6	4.7	134	
Left	748.3	1.4	17	
Right	749.4	0.8	14	
Left	750.7	1.4	194	
Right	754.7	0.9	118	
Left	755.8	3.4	400	
Right	759.2	2.5	124	
Left	762.0	3.6	369	
Right	766.4	2.8	296	
Left	767.6	5.6	591	

TABLE No. 2—(*Continued*).

BANK.	DISTANCE FROM MOUTH. MILES.	LENGTH. MILES.	CAVING PER ANNUM. 1 000 SQ. YDS.	CHARACTER OF BANK.
Right	772.5	0.7	28	
Left............	772.7	3.0	273	
Left............	775.8	3.6	197	
Right	777.4	1.4	42	
Island..........	779.0	0.3	28	
Left............	780.2	2.0	166	
Right	781.2	0.5	11	
Left............	782.7	2.2	82	
Right	783.7	4.9	329	
Left............	787.4	3 2	211	
Right	789.4	6.0	1073	
Left............	792 2	2.4	234	
Island..........	796.0	0.5	6	
Island..........	796.7	1.8	152	
Right	796.4	5.8	276	
Right	800.8	1.3	17	
Right..........	802.4	1.6	56	Sand and silt.
Totals........	....	818.15 miles.	50 019 000	

	Miles.	Square Yards.
Total caving left bank per annum..................................	411.05	26 723 000
Total caving right bank per annum..............................	330.3	19 893 000
Total caving islands per annum..................................	76.8	3 403 000
Total average caving per mile of river per annum...............	......	62 338
Average caving per mile of river, right bank....................	......	24 804
Average caving per mile of river, left bank......................	......	33 304
Average caving per mile of caving bank, right bank...............	......	65 041
Average caving per mile of caving bank, left bank................	......	60 228

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

601.

(Vol. XXVIII—June, 1893.)

FINAL REPORT OF THE COMMITTEE ON STANDARD RAIL SECTIONS.*

To the President and Members of the American Society of Civil Engineers:

Your Committee on Standard Rail Sections have the honor to submit the accompanying series of rail sections (Plates LVIII. to LXX) and the following report as their final recommendation, and ask to be discharged.

Since the progress report of the Committee, which was presented and accepted at the Annual Meeting of the Society, January 21st, 1891, your Committee has held a number of meetings and conducted an extensive correspondence with many of the Chief Engineers of the railroad systems of the country.

The carefully prepared reports of the Committee of the Society on "The Proper Relation to each other of the Sections of Railway Wheels and Rails," and the papers and discussions of the Society, called forth by them, gave your Committee valuable data as the basis of their work. The first result of their deliberations was the preparation and discussion of several series of rail sections. As will be seen by reference to the progress report, there were originally considerable differences in the views of the several members. Correspondence, observation of the

* Presented at the Business Meeting of the Annual Convention, August 2d, 1893.

results obtained from rails in actual use, and discussion, have reconciled these differences so that your Committee are able to present a final report.

As the mileage of practically straight track so much exceeds that on curves, it seemed wisdom to select sections which would give the most satisfactory results on the greater percentage; if, at the same time, such service would extend to curved track, so much the better. We are satisfied that the sections recommended are the best for straight track, and that if the rails are properly laid they will do well on curves.

Our investigation developed that the greatest difference of opinion among the railroad engineers of the country as to rail sections was upon the proper radius for the top corners of the rail heads. In the correspondence which we present as an appendix to this report, it will be observed that this point is the most discussed. Most of these letters were received in reply to a final circular letter of inquiry, which was sent to the Chief Engineers of every railroad having 100 miles and over of track. Fifty-five replies were received, and of these we present those giving decided opinions.

In deciding upon a series of sections, your Committee have given consideration to the manufacturing details of rail making, while seeking designs whose forms would be best adapted to meet the various requirements of traffic.

To have a smooth track, it is absolutely necessary that the surface and line of the rails shall be without lumps and kinks. To obtain such rails it is of importance that the metal in the head and flange of the section should be as nearly balanced as economy will permit, thereby permitting the hot metal in the just-rolled rail to cool with the least internal strain, and thus, when cold, to be as nearly as possible straight in all directions, thus avoiding excessive "gagging" in the final cold straightening. The importance of this increases with the amount of metal in the section. We decided upon 42% of metal for the head, 21% for the web and 37% for the flange. The other constant factors are: top radius of head, 12 ins.; top-corner radius of head, $\frac{5}{16}$ in.; lower corner radius, $\frac{1}{16}$ in.; corners of flange, $\frac{1}{16}$ in.; side radius of web, 12 ins.; top and bottom radii of web, $\frac{1}{4}$ in.; angles of under side of head and top of flange, 13°.

As the grain or "fineness" of "hot-rolled" steel is governed by the work applied to it as its heat decreases, and as we are convinced

that the wearing qualities of rails largely depend on the closeness of the grain of the steel in their heads, we have sought to design heads which, so far as permitted by the other proportions of the sections, will be affected to the greatest extent by the pressure or work of the rolls.

One of the difficulties in rail manufacture is obtaining perfect flanges. The amount of metal being much less in the flange edges than elsewhere in the section, it cools more rapidly; hence, if the flange is both wide and thin, difficulty will be experienced in making it fill out to the full designed width, and also in preventing the development of flaws, which, if detected, will condemn the rail as first quality, but which may be so concealed as to escape detection, and exist as a constant menace to the safety of the rail. These considerations influenced us in designing our flange sections.

At the meeting of the Committee which was held in the Society's House on December 2d, 1892, all of the members present congratulated themselves upon the—to them—satisfactory progress of their labors, and separated, little thinking that before another meeting of the Committee could be held the hand of death would be laid upon one of the members of the Committee. H. Stanley Goodwin was not present at that meeting, official duties preventing at the last moment; but he telegraphed his views, and later wrote the Secretary of the Committee endorsing the Committee's proceedings. To know Mr. Goodwin was to respect him; to be thrown intimately with him was to yield the warmer tribute of friendship. Your Committee unite with all the members of the American Society of Civil Engineers in deploring the loss of so valued a member, and one who was so useful to his fellow men.

We have the honor to remain,

G. Bouscaren, *Chairman.*
Foster Crowell.
Virgil G. Bogue.
S. M. Felton.
J. D. Hawks.
E. T. D. Myers.
Samuel Rea.
Thos. Rodd.
A. M. Wellington.
F. M. Wilder.
Robert W. Hunt, *Secretary.*

I concur in the foregoing report in all respects except one, the width of the heads. If the same wheels are to run over all rails, the portion of the rail which comes in contact with the wheel should always be of the same form. Taking the 80-lb. rail with its $2\frac{1}{2}$-in. head as standard, the same width of head should be maintained for all sections likely to be used. The slight reduction in width of head proposed for the 60-lb. and intermediate sections is comparatively unobjectionable, and I consented to approve the whole report if the same rate of variation had been maintained for the larger sections; the variation in width would then not exceed $\frac{1}{8}$ in. or $\frac{1}{16}$ in. from the mean. The present large variation of $\frac{1}{4}$ in. from the mean to the maximum section is too great, and I cannot accept this portion of the report. I present the sections herewith appended, Plates LXXVI to LXXIX.

George S. Morison.

APPENDIX.

Northern Pacific Railroad Company,
Chicago, Ill., November 30th, 1892.

I have forwarded this morning, by Adams Express, a roll containing tracings of 103 sections of 66-lb. rail in track on our line between Logan and Butte, Mont. I also enclose a report on this matter from E. H. McHenry, Principal Assistant Engineer, dated November 15th.

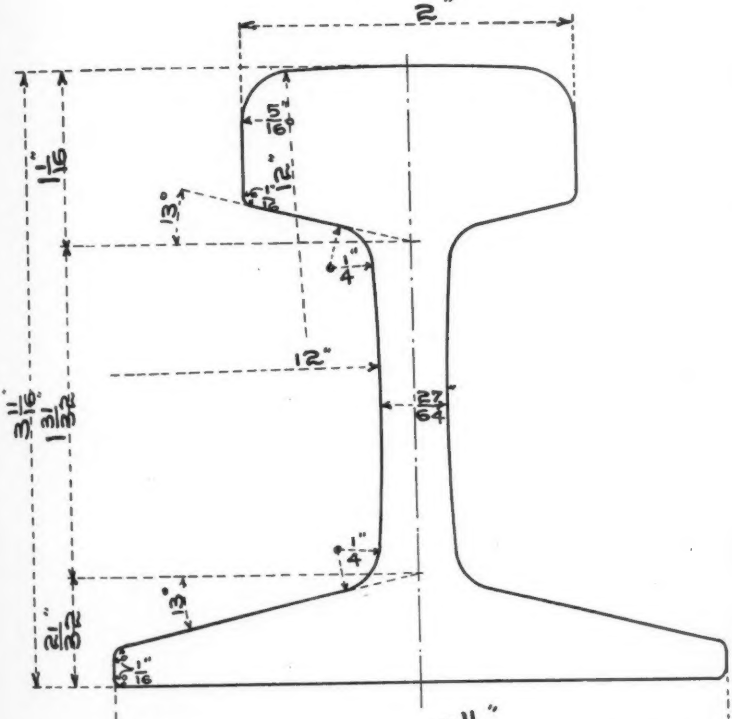
J. W. Kendrick,
Chief Engineer.

Tacoma, Wash., November 15th, 1892.

J. W. Kendrick, Esq.,
Chief Engineer.

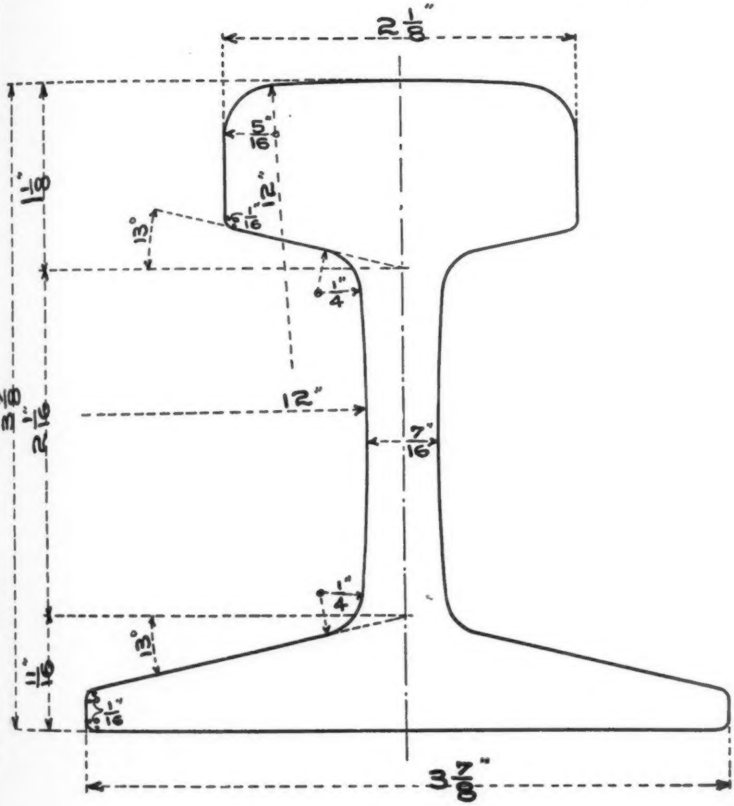
Dear Sir,—I send you herewith tracings of 103 rail sections taken on the Logan to Butte Division of the Northern Pacific Railroad. It is very hard to deduce any general conclusions from the rail sections contained in the sheets. The wear seems to be variable without appreciable cause, the rails laid on light curves showing, in many cases, much greater wear than those on sharper curves, and *vice versa.* The notes show the original line has been lost, and the curves, almost without exception, have altered radii from those laid out. Mr. Relf has shown the actual radius of the curve at the point where the section is taken, which has probably been computed from the ordinate. Mr. Relf's note, on the last sheet of the sections, gives the ordinary speed of trains at from 10 to 15 miles per hour. This is obviously intended for the ascending rate, and he has omitted to take into account the fact

PLATE LIX.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XXVIII, No. 601.
REPORT ON STANDARD RAIL SECTIONS.



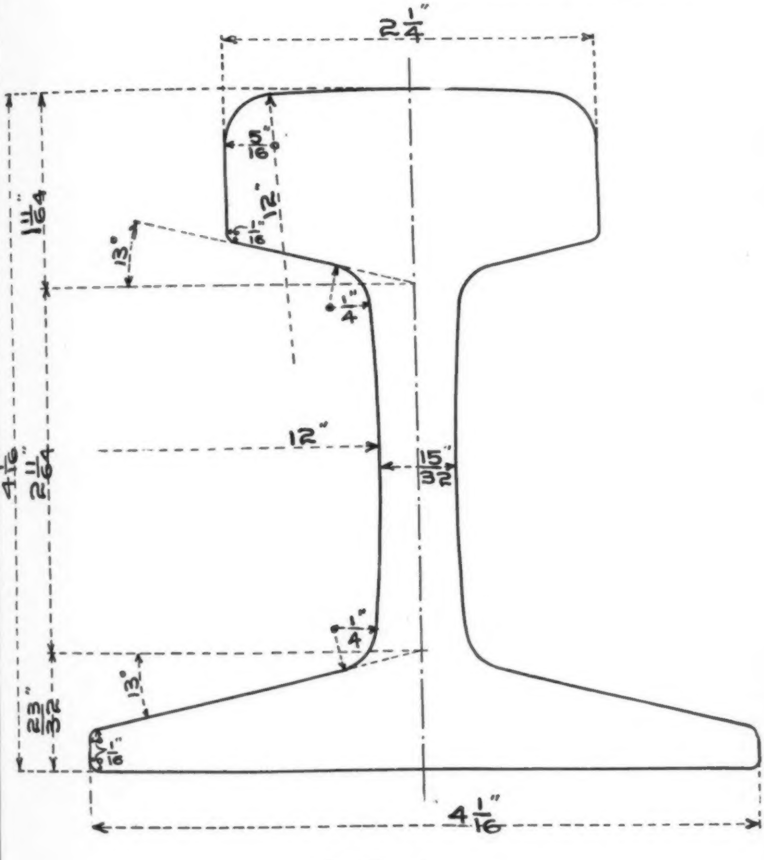
45 LBS.

PLATE LX.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XXVIII, No. 601.
REPORT ON STANDARD RAIL SECTIONS.



50 LBS.

PLATE LXI.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XXVIII, No. 601.
REPORT ON STANDARD RAIL SECTIONS.



55 Lbs.

PLATE LXII.
TRANS. AM. SOC. CIV. ENGRS.
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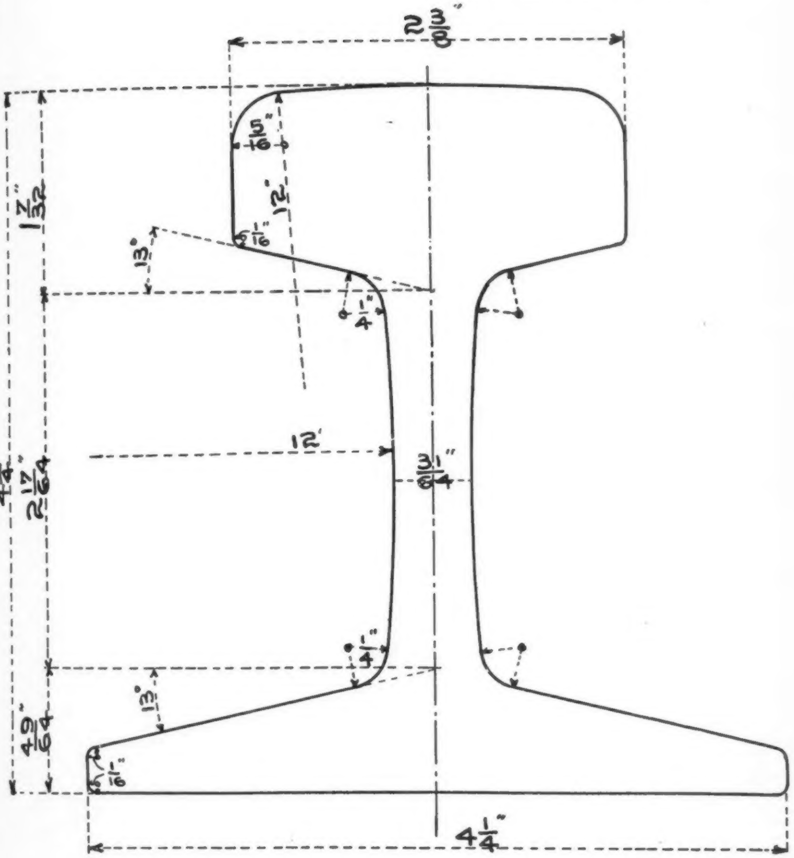
REPORT ON STANDARD RAIL SECTIONS.



60 LBS.

PLATE LXIII.
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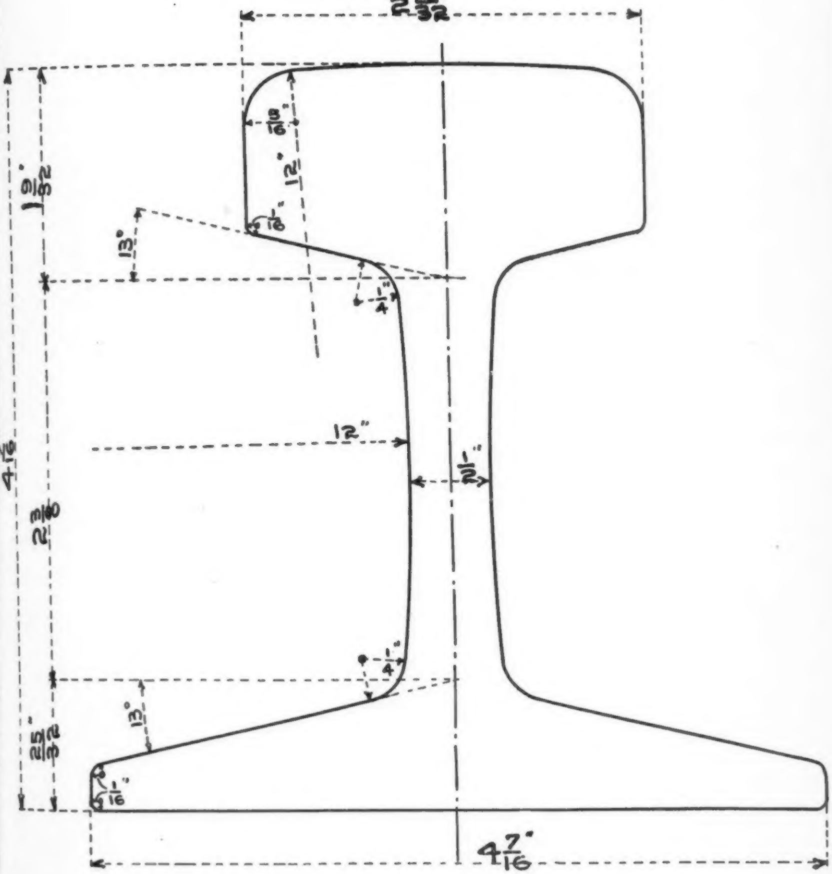

65 LBS.

PLATE LXIV.
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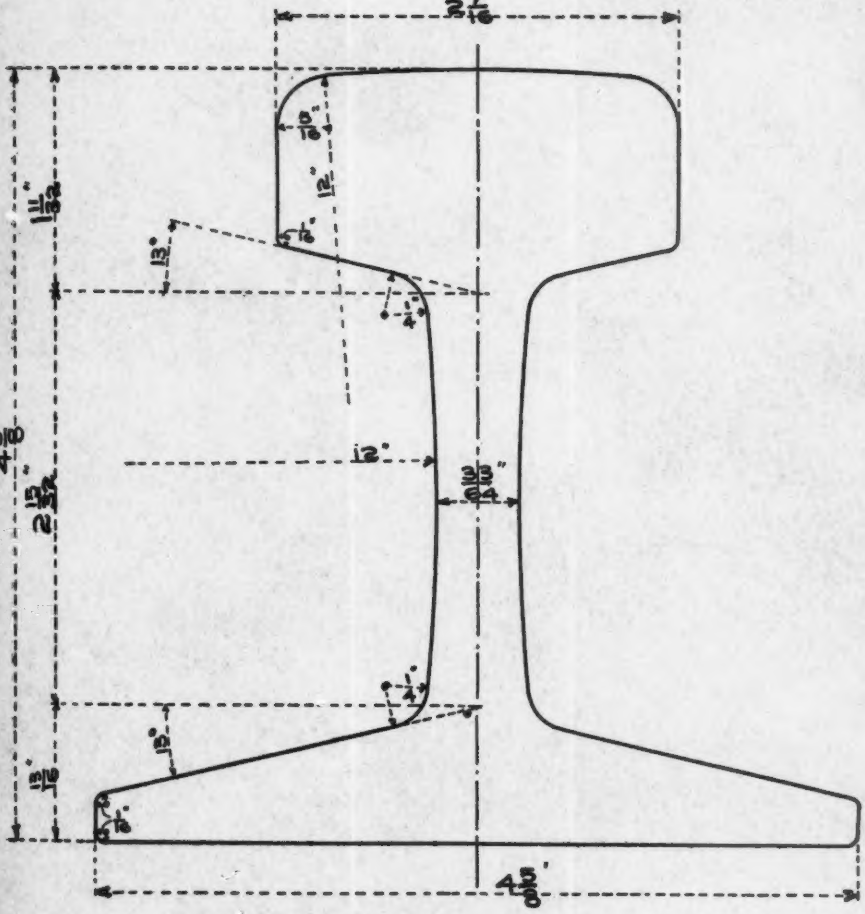
REPORT ON STANDARD RAIL SECTIONS.



70 LBS.

PLATE LXV.
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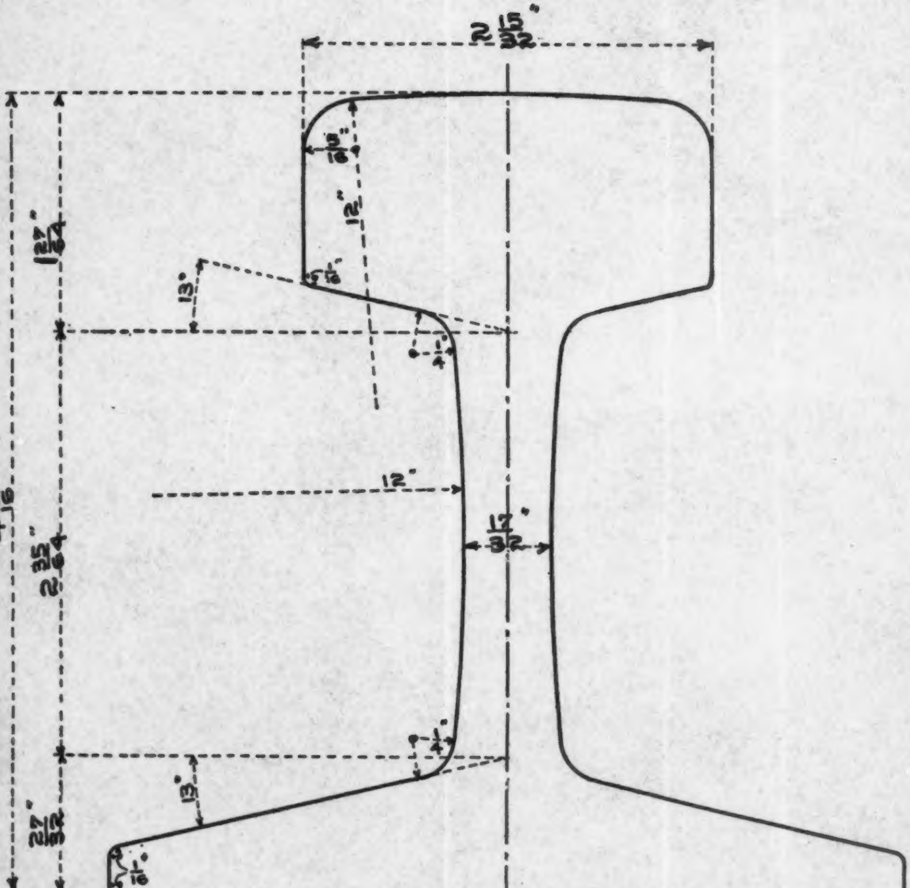

75 LBS.

PLATE LXVI.
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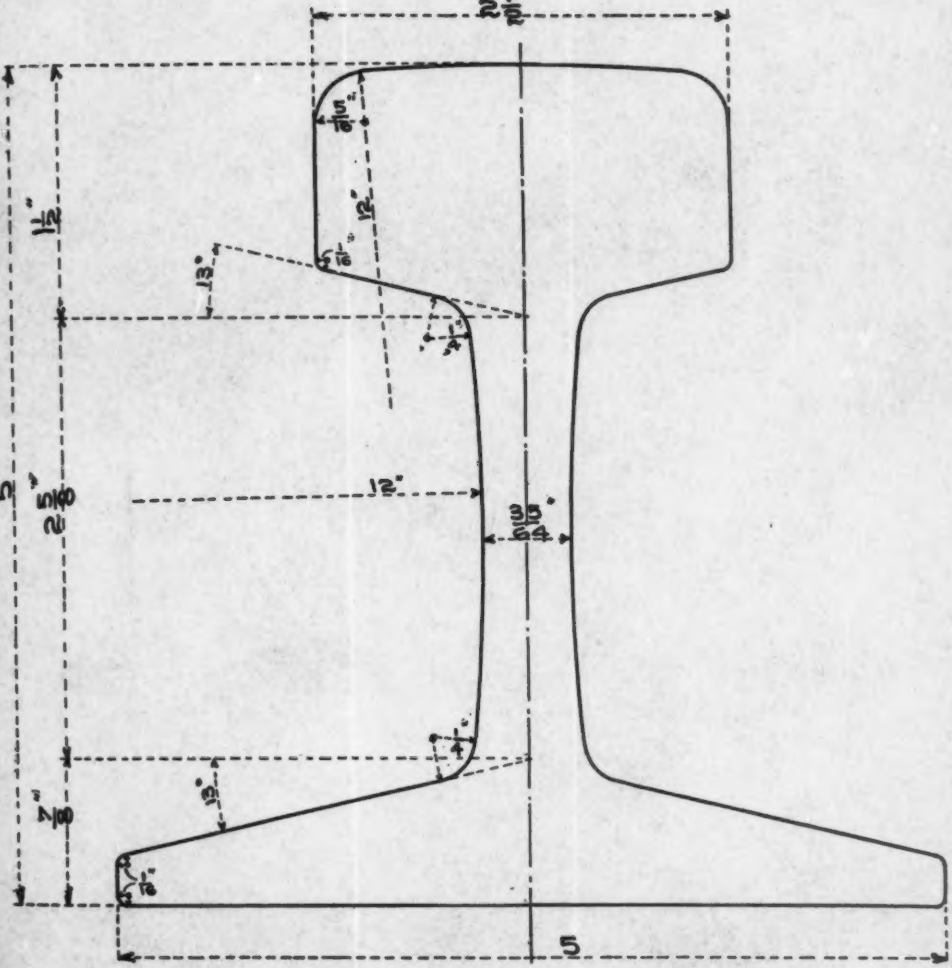
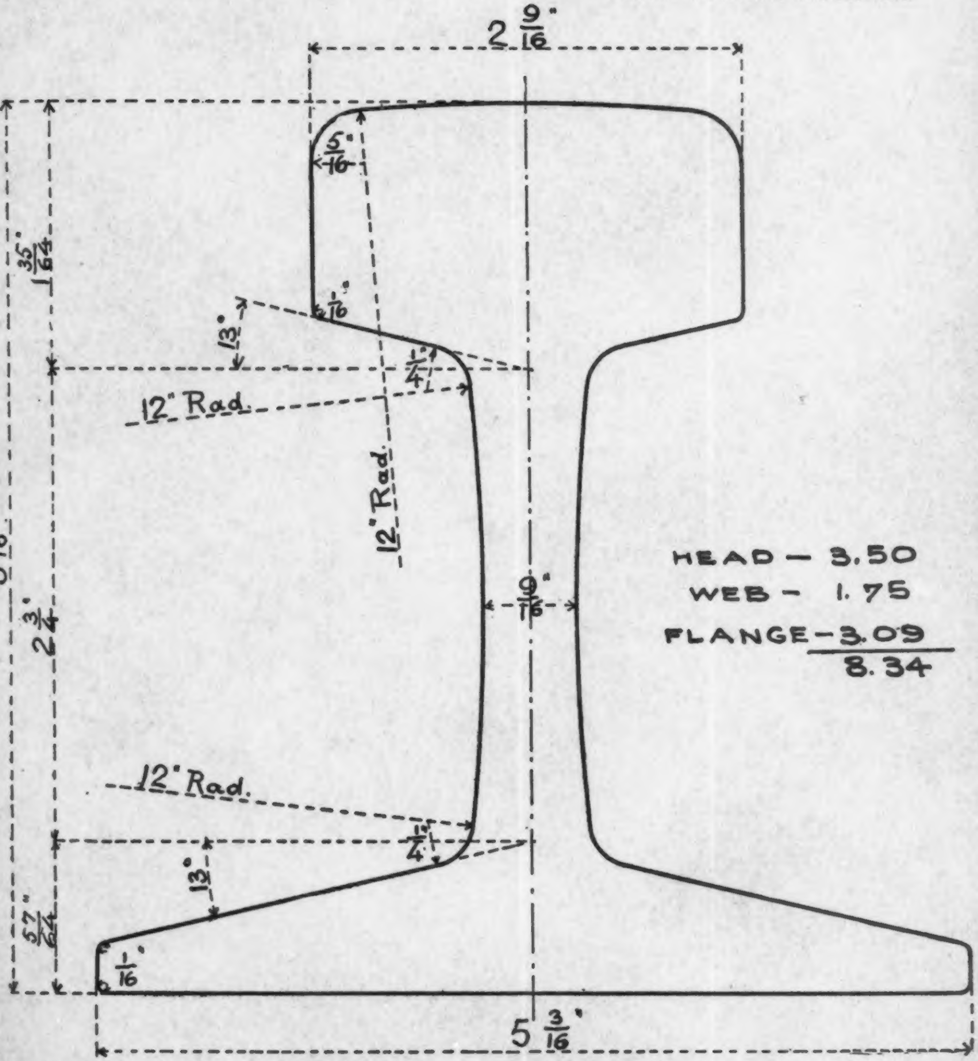


80 Lbs.


2 9/16"
5/16"
1 35/64"
1/16"
13°
1/4"
12" Rad.
12" Rad.
5 3/16"
2 3/4"
9/16"
HEAD — 3.50
WEB — 1.75
FLANGE — 3.09
8.34
12" Rad.
1/4"
13°
57/64"
1/16"
5 3/16"

85 lbs.

PLATE LXVIII.
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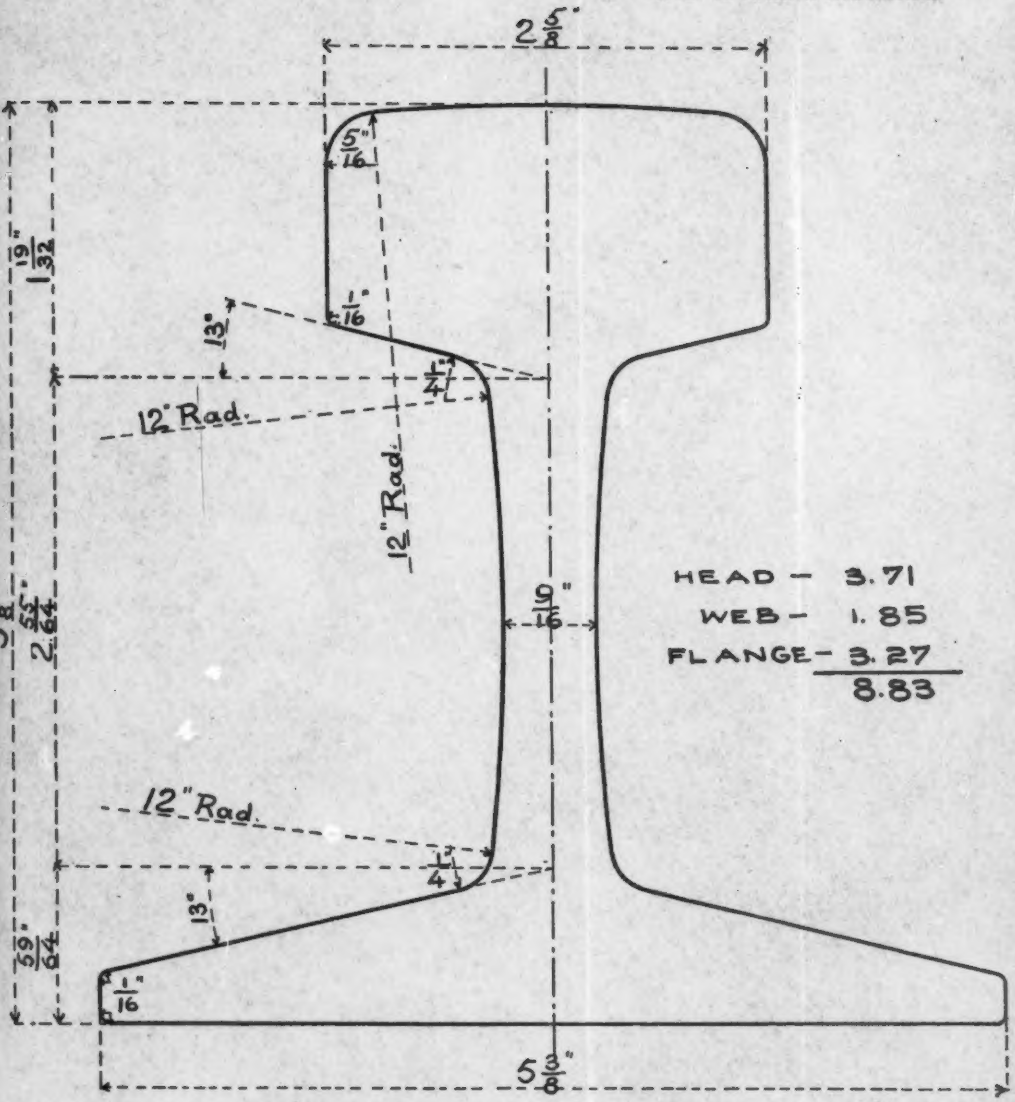
REPORT ON STANDARD RAIL SECTIONS.



90 lbs.

PLATE LXIX.
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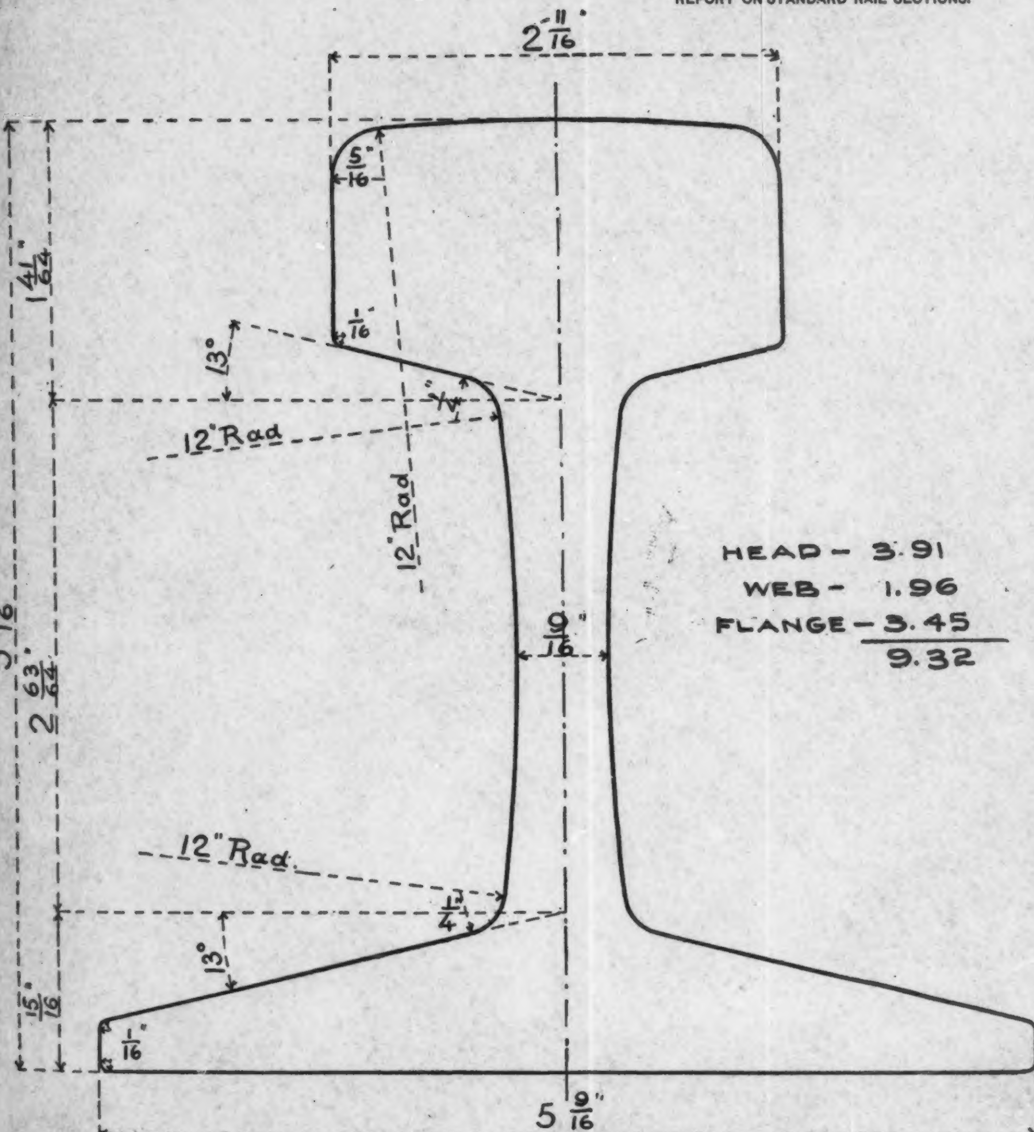
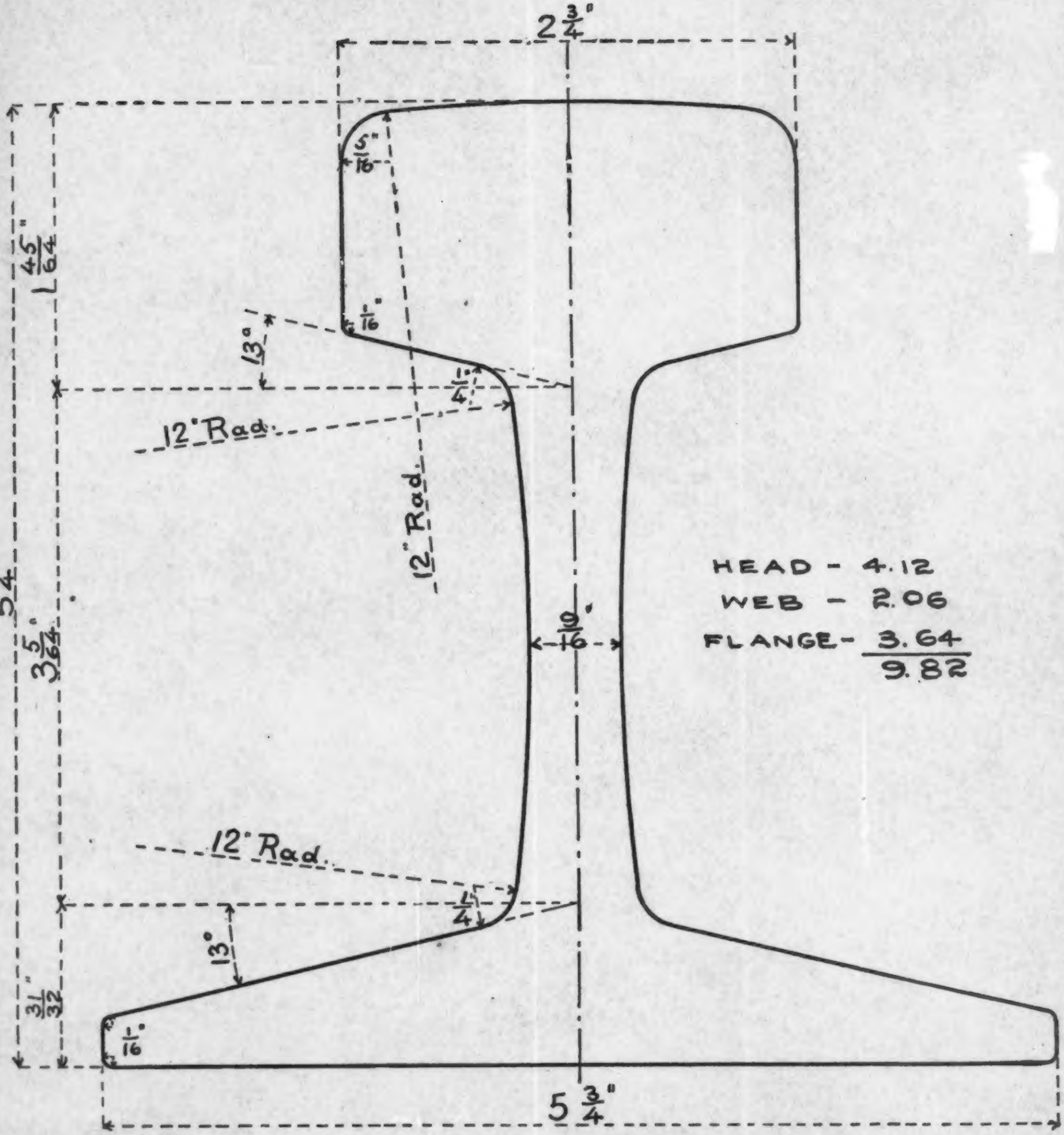
REPORT ON STANDARD RAIL SECTIONS.



95 lbs.


2 3/4"
5/16"
1 45/64"
1/16"
13°
1/4"
12" Rad.
12" Rad.
5 3/4"
3 5/64"
9/16"
HEAD - 4.12
WEB - 2.06
FLANGE - 3.64
9.82
12" Rad.
1/4
13°
31/32"
1/16"
5 3/4"

100 lbs.

that the rate on the descent is very much greater. I think the correct method is to put up the curves for a speed very little in excess of that used by the ascending trains, and to hold down the speed on descending trains by strict orders, and, by proper supervision, to see that these orders are carried out. Apparently, the effect of elevating the outer rail too much would be in the direction of decreasing train resistance, as the centrifugal force would not then overbalance the tendency for the flanges to seek the lower rail, due to the effect of gravity. In practice, however, I am convinced that this does not occur, and that the train resistance is actually increased. The car floors are no longer balanced, and an unequal proportion of the weight falls on the lower trucks, preventing them from conforming properly to the curve. This is especially noticeable when a train traverses a reversing curve. The trucks must then swing through a considerable arc in changing from the radial position they have assumed on one curve to a radial position on the opposing curve; and as this shifting is done under very unfavorable conditions, the weight being thrown upon one side instead of balanced at the center, it seems to cause considerable extra train resistance. Calculating this resistance by the decrease in train speed, in one case, I found it to be equivalent to an additional rise of 1.1 ft. in the length of the two curves. By a reversing curve I do not mean, of course, curves without a reversing tangent, but curves close enough together so that the train will be on both curves at the same time. In the particular case in point, I feel convinced that a large amount of the rail wear is owing to the undue elevation used.

It makes it still more difficult to generalize from the sections given, as it is not at all certain that the indicated rail wear is due to the existing conditions, as the causes which lead to the excessive wear may have disappeared with the re-adjustment of track. In many cases the sections show an apparent wear on the inner face of the low rail. In some cases this is palpably wrong, and in others may have been due to a deficient original section. Where the characteristic deformation or change of section exists that is caused by the metal flowing under the wheel tread, it is certainly wrong, as any flange wear, if it existed, would prevent the appearance of bulging or swelling, which is especially noticeable in sections Nos. 44, 72, 78, 94 and 96. In section 34 it is possible that insufficient gauge may account for some of the apparent wear on the inner face of the low rail. As you will note, the gauge at this point is 4 ft. $8\frac{3}{4}$ ins.—should be 4 ft. $9\frac{1}{8}$ ins. Insufficient gauge will, in all probability, account for wear of this character in similar sections to the above when it is taken into account that the gauge has probably, in a great number of cases, been too tight when originally laid, although the gauge does not now show it, on account of the track spreading and also the great amount of rail wear.

It is my belief, derived from experience, that excessive and unusual rail wear occurring locally is almost invariably due to insufficient gauge. Variations in the temper of the steel may sometimes cause the same effect; but rail wear due to this cause may be usually detected, as the effect upon contiguous rails is not uniform.

While the results obtained have not been conclusive, or very satisfactory in many respects, I think it may be definitely stated that nothing has been found to cause any change of opinion regarding the propriety of using the sharp-cornered rails; in fact it is obvious from the sections that if the corners had been larger in the beginning, the rate of rail wear would have been accelerated, which is shown to some degree in the sections on the last sheet.

I note Mr. Hunt asks for information in regard to sharp wheel flanges, and particularly whether such flanges have been found on both wheels on the same axle. I feel that I am able to shed some light on this subject, and I do not remember ever having seen it noted in any of the various discussions regarding the proper rail section. I wish to assert my belief that a large part of the excessive wear observed on both wheels and rails on new track is due to the chisel action of the sharp-cornered rail at the joint cutting the flanges of the wheels, and scoring them in such a manner that their reaction upon the rail is in turn equally destructive. In support of this I will point out the results obtained during the construction of some of our new lines. You will remember that at the time the Butte line was constructed we were much annoyed by the extraordinary flange wear on the engine drivers. The wear was abnormal and occurred on both wheels on the same axle alike. The principal wear was on the forward and rear driving wheels, the intermediate wheels, even if flanged, showing but very little wear. This might be expected, as the flanges on the intermediate wheels would rarely come in contact with the rail.

This phenomenon bothered me greatly, and I made a large number of examinations with a view to determining the cause. During several track inspections I noted that the amount of new filings or chips of metal along the track were especially noticeable, indicating that the wear of the flanges and rails was excessive. This line of worn metal was continuous along the outside rail of every curve. The amount of filings was increased at the joint, some joints showing much mcre wear than others. It was noticeable that the filings increased in amount wherever the alignment between the ends of the adjacent rails was not perfect. Also, that where the expansion was insufficient, in addition to the alignment not being perfect, that the amount was increased. Where the expansion was too great, even a considerable offset did not produce similar results, as in the other cases. An inspection of the engine drivers showed that they were not worn smooth and bright as in ordinary practice, but were extremely rough,

being scored or cut in very perceptible curves. The shape of these curves was that of a modified cycloid, showing the characteristic loop at the beginning of the reverse curve. This led to the conclusion that the extraordinary rate of wear was unquestionably due to the effect of the sharp corner at the end of the rail, which acted precisely as a sharp cutting tool in every case where there was not a perfect alignment. This perfect alignment it is practically impossible to secure in curving rails for very sharp curves, for obvious reasons. Acting upon this theory, I predicted that the excessive wear would disappear in time and become no longer noticeable, which has since proven true, and my theory has been demonstrated to be correct in a number of other cases.

While this wear went on in the same manner in the case of rails laid on the main line it was not so noticeable, as the number of wheels that passed over the ground was very much greater, and the percentage of mileage run over the new steel was an insignificant proportion of the whole. In the case of our construction engines on the track laid entirely with new steel the result was different, as the mileage run was entirely upon new steel. The wear of the flanges due to this cause was not confined to the wheels alone; the engine flanges, being roughly scored, in turn wore the rails, and there was consequently, first, the action of the rail ends on the engine flanges, and second, the reaction of the roughened flanges against the rail throughout its length between the joints. Yours truly,

E. H. McHenry,

Principal Assistant Engineer.

Pennsylvania Lines West of Pittsburgh,
Pittsburgh, Pa., November 3d, 1892.

In answer to your inquiry, I have no personal experience with rails with sharp top corners to their heads. The Pennsylvania Railroad pattern, as is well known, has large top-corner radius.

My personal opinion is that a sharper top-corner radius than we use is desirable. I have not expressed this, so far as I can recollect, in reply to the questions of the former committee, of which I was a member, but I have expressed it in other ways when this subject has come up, both in my official capacity and as a member of the Society.

Yours truly,

Thomas Rodd,

Chief Engineer.

The section shown in Fig. 1, Plate I, is the new pattern used by the Northern Pacific and the Chicago, Burlington and Quincy lines.

PITTSBURGH, PA., September 13th, 1892.

In response to your communication of September 1st, 1892, I beg to refer you to Vol. 21, pages 154 and 247, of the *Transactions* of the Society for my sentiments on the question under consideration by your committee, from which I have no reason to deviate at this time.

You know the rail sections in use on our lines in 1889, when I gave expression of my views in the contributions to the discussions above referred to; and you know also the changes made in the sections since that time. I almost feel that you will agree with me that our progress towards the "ideal" is rather slow.

Very sincerely yours,

M. J. BECKER.

BURLINGTON & MISSOURI RAILROAD IN NEB.,

C., B. & Q. SYSTEM,

LINCOLN, NEB., September 23d, 1892.

Answering your circular-letter of the 1st. We laid about 100 miles of this sharp-cornered rail on our Deadwood line, where curvature runs up as high as 16°. We found that the sharp corner of this steel, both on curves and on straight lines, wore off and assumed a shape with a large radius and flaring side, conforming somewhat to the shape of the flange of the wheel. We found that after the rail was worn, which had been in the track now a little over two years, that we could increase our train load by about one-seventh. We also found that wear on our car wheels was very materially diminished after the rail was worn to the shape above described.

We have a good many miles of this same sharp-cornered rail on other lines where grades are very light and curvature very slight, but have not yet been able to see the ill effects of the sharp corners and straight sides; but the test on the Deadwood line is conclusive that the section is wrong entirely (Fig. 1, Plate LXXI).

Yours truly,

I. S. P. WEEKS.

NORFOLK AND WESTERN RAILROAD CO.,

ROANOKE, VA., October 12th, 1892.

In answer to your first question I beg to advise that on this road we have not had very direct experience in the use of rails having what is now designated sharp top corners to their heads. The sections of rails used on this road prior to June of this year have had the radius of the head and the top corners of head of such dimensions as may be best classified as medium. The standard rail section for the main line and extensions of this road, from 1886 until June, 1892, has been Pennsylvania Steel Company's Section No. 2, or corresponding sections

of other mills. (All these sections are shown in Figs. 2, 3 and 4, Plate LXXI.) The radius of top of heads in these rails is either 10 or 11 ins., and the top corner radii are either $\frac{11}{32}$ or $\frac{14}{32}$ in. This 67-lb. rail was put in our main line between the years 1886 and 1892, displacing 60-lb. rail and 56-lb. rail, which rail has been transferred for use on sidings, short branches, etc. Figs. 5 to 12, inclusive, Plates LXXI and LXXII, show the various sections of rail in use on the main line of this road prior to its displacement by the 67-lb. rail. You will note the radius of top of the head is generally either 10 or 13 ins., and that the upper corner radii of the head are $\frac{7}{16}$ in., the same as in the 67-lb. rail.

Our experience on this road, where we have on the main line from Norfolk to Bristol numerous curves varying from 4 to 8°, and where we have on other divisions of the road some curves as high as 12°, has been that rails of the forms shown have been cut quite badly on these curves by the wheel flanges. From a very careful study into this matter by our officials early this year we came to the conclusion that any new section for a heavy rail should have vertical sides and a sharper top corner radius. Further, that the width of the head should be somewhat wider in proportion than that of the 67-lb. rail heretofore used. In June, 1892, it was decided to use on those portions of our main line subject to the heaviest traffic 85-lb. rail, and the section shown in Fig. 13, Plate LXXII, was adopted by us as standard. This is the section previously adopted by the Baltimore and Ohio Railroad. You will note that this section has a top radius of head of 12 ins., and radius of top corners of $\frac{1}{4}$ in., and has vertical sides. This section, therefore, represents the views of the officials of this road as to the best form of rail to withstand the wear to which it is subjected. We think the sharp top-corner radius and the vertical sides postpone to a comparatively late day the subjection of the rail to the grinding wear of the flanges of wheels on the outer rail of curves ; or wear at any other point where from the inequalities of the wheels or irregularities in the construction of the trucks the flanges of the wheels have a tendency to bear hard against the sides of the rails.

* * * * * * * * *

I have only to add to this that in the case where a rail on the outside of a curve has been worn down on the side, so that the section corresponds practically with the flange of the wheels, then the wear, both on the rail and on the wheel, produced by the grinding action of the wheel must be extremely rapid. This is certainly an argument for rails with comparatively short top corners and for rails having vertical sides.

I trust the above answers give you the necessary information.

Yours truly,

CHAS. S. CHURCHILL,

Engineer Maintenance of Way.

MICHIGAN CENTRAL RAILROAD COMPANY,
DETROIT, MICH., September 15, 1892.

The Michigan Central, with which I am connected, has during the last four years laid 40 000 tons of 80-lb. rail with the ¼-in. top-corner radius (Fig. 14, Plate LXXII). It is giving perfect satisfaction as far as the corner radius is concerned, and I see no reason why the top-corner radius should be any larger than ¼ in. I have put down a few experimental rails having perfectly square top corners and flat tops, and find that carrying out the idea to such an excess will show no bad results.

Yours truly,
J. D. HAWKS,
Chief Engineer.

BOSTON AND MAINE RAILROAD,
BOSTON, MASS., November 7th, 1892.

The 75-lb. steel rail (Fig. 15, Plate LXXII) we are now laying has what you would call "sharp top-corners."

Of course our engines, having previously run on round-top rails, have drivers more or less worn, and the new rails wear more on the outside than on the center : there will always be a tendency that way, but, taking everything into account, I think the flat-top, sharp-cornered rail is the best. One of the principal reasons for their use is that we shall have less hollow drivers.

Yours truly,
H. BISSELL,
Chief Engineer.

NEW YORK, LAKE ERIE AND WESTERN RAILROAD COMPANY,
NEW YORK, September 13th, 1892.

Below please find my answer to the question asked in your circular of the 1st inst. about steel rail sections.

My experience with such rails as are referred to has extended over a period of three years, and has been entirely satisfactory. The radius used in the corner of the heads of these rails is ¼ in. (Fig. 16, Plate LXXII).

I have put down about 40 000 tons and have heard no complaint about sharp wheel flanges.

Respectfully yours,
CHAS. W. BUCHHOLZ,
Civil Engineer.

THE DULUTH AND IRON RANGE RAILROAD COMPANY,
DULUTH, MINN., September 19th, 1892.

The opinion has been with me one of gradual growth, from the beveled to the straight (vertical) sides of the ball, from the ¾-in. radius at top corner in a 56 to 60-lb. rail to the ¼-in. radius in the 80-lb. rail

we are now using in renewals (Fig. 14, Plate LXXII). Of these latter we have put down about 4 500 tons, Michigan Central pattern.

From the information at hand a noticeable decrease of sharp flanges in our car-wheels can be attested, and corroborative testimony is found in the condition of the rail heads on the gauge side; dull, almost rusty in the 80-lb. rail; bright, silvery on the corner and side of the 60-lb. rail with the large radius of the corner. Just what proportion of this may be due to the increased resistance offered by the wider, flatter head of the 80-lb. rail to the lateral variations in the path of the wheels I am not able to indicate; but there is less nosing of individual cars on the 80-lb. than on the 60-lb. rail; and I am of opinion that there is also a perceptible difference between rails of equal weights (60-lb.) in favor of the straighter side and small top-corner radius.

You are aware that our business is that of hauling iron ore between Ely and Two Harbors; the alignment consists of 80% tangents and 20% curvatures (6° max. curves); the equipment consists of consolidated engines 104 000 lbs. on 14-ft. wheel base; ore cars 24½ ft. center to center of couplings; average weight loaded, 75 000 to 76 000 lbs., all provided with Westinghouse automatic brakes.

Nosing is a local term, and describes the path of the individual ore cars relative to the left and right rails in a zigzagging course. It obtains, no matter how perfect the track may be, and is due largely to the position of the load between the trucks in a concentrated form, and is a very destructive agency to track and bridges.

Yours truly,

K. Augst,

Chief Engineer.

Long Island Railroad Company,

Long Island City, N. Y., September 19th, 1892.

Dear Sir,—In reply to yours of the 1st inst I beg to state that my experience with rails has been almost entirely with the P. R. R. and the P. & R. R. R. standard forms, and from this experience of 13 years I have been induced to adopt as a standard for this railroad a rail having 12-in. radius for top of head, with radius of top corners of ¼ in.

I have laid this spring on this railroad 5 000 tons of the above-mentioned sharp top-cornered rails.

Yours truly,

P. D. Ford,

Chief Engineer.

Chicago, Rock Island and Pacific Railway Company,

Davenport, September 13th, 1892.

Dear Sir,—In reply to yours of the 1st on the subject of rail sections, I would say: This company has not gone into the rail question

scientifically. Some years ago we adopted the Lehigh Valley (Goodwin) pattern of 70-lb. rail, and can only say that it is doing good service. Whether another shape of rail would have done better service, I do not know.

Yours truly,

A. Kimball,

Assistant to President.

Atchison, Topeka and Santa Fé Railroad Company,
Topeka, Kans., October 3d, 1892.

Dear Sir,—I have never had any experience with rails of this class (with sharp top-corners). I hand you herewith a print (Fig. 17, Plate LXXIII) showing the general form of all sections which are now in use on the Santa Fé line, from which you will see that all have $\frac{3}{8}$ in. radius of corner. Our 66-lb. section has been in use about a year and a half and has so far given very good results.

Yours truly,

James Dun,

Chief Engineer.

Grand Trunk Railway of Canada,
Montreal, October 11th, 1892.

I may say that, generally, for many years we have adopted a series of "Holley" patterns of which a section is shown in Fig. 18, Plate LXXIII, and that our experience is satisfactory.

Yours truly,

E. P. Hannaford,

Chief Engineer.

Colorado Midland Railway Company,
Colorado Springs, Colo., September 27th, 1892.

I am inclined to favor very strongly the use of a rail, shaped approximately like the standard D. and R. G. rail, a section of which I send you (Fig. 19, Plate LXXIII), as there can be no question the rail will stand much longer wear on a curve than the Colorado Midland 65-lb. rail (Fig. 20), before it would assume the shape of a worn piece of the C. M. rail.

The web of the D. and R. G. rail, which is $\frac{7}{16}$ in. thick, seems light for a 65-lb. rail, but a two-year test in the track would indicate that it is strong enough to endure the strain to which it is exposed.

Yours very truly,

B. H. Bryant,

Chief Engineer.

NEW YORK CENTRAL AND HUDSON RIVER RAILROAD COMPANY,
NEW YORK, October 4th, 1892.

With regard to the use of sharp top-corner rails on this road I would say that with the close of the present season there will be very nearly 100 000 tons of rails of 80-lbs. weight per lineal yard laid in the main passenger tracks of this road, between New York and Buffalo; part of which is what we term "old model" 80-lb. rail, which has a height of 5 ins., radius of top, 12 ins.; and radius of top corners, $\frac{5}{16}$ in. Since the first of this year this model has been slightly revised. The new model 80-lb. rail has a height of $5\frac{1}{8}$ ins., top radius of 14 ins. and corner radii of $\frac{1}{4}$ in. Last spring we relaid track No. 1 at West Albany with the old model 80-lb. rail. Some two months ago track No. 2, at the same point, was laid with the new model rail. A late examination of these rails shows that at the present time they are wearing excellently well, seem to fit the template of the wheel perfectly, and to fit over the entire head of the rail, but, if anything, better on the new model rail with the $\frac{1}{4}$-in. corners and flat top than on the old model. Mr. P. H. Dudley has kindly furnished me with the results of his late examinations on some other roads; and as the information is, I think, valuable, and may not possibly reach you in any other way, I will herein give you a brief note of the same: The B. and A. R. R. has laid 17 000 tons of 95-lb. rail, with a head 3 ins. in width, 14 ins. top radius, and $\frac{5}{16}$ in. corner radii. These rails on curves of 4 and $4\frac{1}{2}°$, and on gradients of 52 to 85 ft. per mile, after 15 months service, show a wheel flange contact on their inner sides of from $\frac{3}{8}$ to $\frac{1}{2}$ in. in depth, which is reported as being less than one-half the similar wear on 72-lb. rail with $2\frac{1}{4}$ in. width of head and $\frac{11}{32}$ in. corner radii—both weights of rail having about the same angle of side inclination. On the 95-lb. rail it was observed that there was very little flow of metal on the inside of the lower rails on curves. The R. W. and O. Div. of this road last year laid 11 000 tons of 70-lb. rail with $\frac{1}{4}$-in. corner radii. These rails are reported as wearing very well. The A. and St. L. R. R. has laid 24 000 tons of 75-lb. rail, and 2 000 tons of 60-lb. rail, all with $\frac{1}{4}$-in. corner radii. The Central Railroad of Vermont has laid 2 700 tons of 75-lb. rail of the same model as the preceding. The Buffalo, Rochester and Pittsburgh has laid 3 000 tons of our new model 80-lb. rail. The N. Y. and N. E. R. R. has laid 10 000 tons of rail with corner radii of $\frac{5}{16}$ in. From general observation on many lines, Mr. Dudley states to me that he has arrived at the conclusion that $\frac{5}{16}$ in. seems to be the best radius of heads of $2\frac{3}{4}$ to 3 ins. width, and $\frac{1}{4}$-in. radius for heads under $2\frac{3}{4}$ ins. width. He also states that under certain conditions there will always be, to some extent, "flow" on the inner edges, but that it is of much less serious amount than that resulting from larger corner radii, which seems to permit a flow of metal from the top of the head to the corners

under the very heavy service of modern locomotives and "30-ton" car-loads. Yours truly,

WALTER KATTÉ,
Chief Engineer.

LOUISVILLE AND NASHVILLE RAILROAD COMPANY,
September 21st, 1892.

The Louisville and Nashville Railroad Company received and laid during the calendar year 1890, 10 388 tons of 70-lb. rails; during 1891, 11 345 tons of the same section; and will lay during the present calendar year 12 000 tons, most of which has already been placed in track; making a total of 33 733 tons.

The ball of this rail (Fig. 21, Plate LXXIII) has a 12-in. top radius, with top corners $\frac{1}{4}$-in. radius, and vertical sides.

The rails laid in 1890 did not show satisfactory results, which was partially due to excessive wear of the corners, on account of the wheels being grooved for the old narrower headed rails, thus causing excessive weight on the outer edges of the ball of the new rails; and partially due to defective material in the rails, which showed extraordinary softness in spite of the fact that the carbon averaged over $\frac{40}{100}$ of 1 per cent.

The 70-lb. rails received in 1891 and 1892 have given much better results, doubtless due to the fact that the grooves in the wheels have gradually worn to fit the new rail section, and also to the better quality of material in the rails.

I anticipate no further trouble on the score of the change in section.

Our Superintendent of Machinery has watched closely the effect of the sharp corners of the new rails on wheel flanges. At first he was of opinion that these sharp corners had a marked effect on the leading wheels of locomotives, and he reported sharp flanges on both wheels of the leading axle in the engine trucks, but seldom found a like condition of affairs to exist on the flanges of wheels of car trucks. More recent observations have led to the conclusion that the sharp flanges caused by the $\frac{1}{4}$-in. radius of top corner of ball of rail is not of serious moment.

I feel satisfied that when a similar section is generally adopted all objections to it will disappear, and better results will be obtained than could be had from the old section with larger top-corner radius.

Yours truly,

R. MONTFORT,
Chief Engineer.

NOTE.—The following communication was received from Mr. Montfort at a subsequent date.

LOUISVILLE AND NASHVILLE RAILROAD CO.

DEAR SIR,—I hand you herewith a map and profile of Baker's Hill Grade on the Henderson Division of the Louisville and Nashville Rail-

road (Plate LXXV), which was laid with our 70-lb. section of rail (Fig. 24, Plate LXXIV) during the years 1890–92.

You will notice that the grade is very steep—4%, or 211 ft. per mile. It extends for about 8 000 ft. The alignment of track is also very crooked; 11° 20′ curves reversing into 12° curves.

There are, I believe, few such grades operated with ordinary locomotives. At Baker's Grade two consolidation engines are in constant service, helping trains up and down the hill.

I am informed by our Mechanical Department that they have been unable to detect that the wear on flanges of wheels has increased appreciably since the round-cornered $58\frac{1}{4}$-lb. (Fig. 25, Plate LXXIV) and 68-lb. rails were replaced by the sharp-cornered 70-lb. rails. This would seem to show conclusively that the sharp corner is not detrimental to the flanges of locomotive wheels.

Very sincerely yours,

R. MONTFORT,

Chief Engineer,

BUFFALO, ROCHESTER AND PITTSBURGH RAILWAY COMPANY,
ROCHESTER, N. Y., September 24th, 1892.

We have been using sharp top-cornered steel rails on our road, and have laid some 5 000 tons of them; we find that they are a great improvement over the old and round-cornered sections. The radius of our 70-lb. rail is $\frac{5}{16}$ in., and of our 80-lb. rail, $\frac{1}{4}$ in.

Truly yours,

WILLIAM E. HOYT,

Chief Engineer.

BOSTON AND ALBANY RAILROAD COMPANY,
SPRINGFIELD, September 12th, 1892.

In answer to yours of September 1st, I will say that our 72-lb. rail, of which we have some 150 miles, has a radius $\frac{1}{32}$ in., and has given good service.

Yours truly,,

W. H. RUSSELL.

FALL BROOK RAILWAY COMPANY,
CORNING, N. Y., September 12th, 1892.

This company has not used rail sections with sharp top corners to their heads until this year, having previously used the 76-lb. standard L. V. R. R. section with $\frac{5}{8}$-in. radius for top corners. This section has not given entire satisfaction, owing principally to its poor lasting qualities, particularly on curves; the outside rail wearing away very much on the gauge side and the inside rail wearing un-

equally in spots along its top, giving it a wavy appearance and causing low spots along the length of the rails as well as at the joints. We came to the conclusion that the softness of the head of this section was owing principally to its large percentage of metal, and therefore in January of this year adopted a 75-lb. rail section (Fig. 22, Plate LXXIII), which was designed almost exactly after the standard adopted by the American Society of Civil Engineers. We have laid this year about 2 000 tons of this 75-lb. section, but it has been in the track too short a time for observations to be of value.

Yours truly,

S. T. Hoyt, Jr.,

Engineer F. B. Ry. Co.

Manitoba and North Western Railway Company, of Canada,
Portage la Prairie, Man., September 29th, 1892.

In reply to your circular-letter of 1st inst., I beg to say that my experience with steel rails has been entirely with those with top corners having a radius of $\frac{1}{2}$ in. I inclose a blue print of the section in use on this road, of which we have 232 miles laid in track, equal to 20 416 tons.

I have had immediate charge of track during the past 18 years laid with rails of this section, and find when properly made and track kept in good order that they have given every satisfaction, both as regards wear of rail and of wheel flange.

I have no reason to recommend a change from our section for a 56-lb. rail. Yours truly,

George H. Webster,

Engineer.

Flint and Père Marquette Railroad,
Saginaw, Mich., September 15th, 1892.

Our standard rail which gives much satisfaction has a radius of $\frac{5}{16}$ in. at the upper corner, $\frac{3}{16}$ in. at the lower corner, and is $\frac{1}{8}$ in. wider at the lower than at the top corner of the head; the radius of the top is 14 ins. and this we find wears very much as rolled; we have some 13 500 tons of this 67-lb. rail. Very truly yours,

George M. Brown.

Florida Central and Peninsular Railroad Company,
Jacksonville, Fla., September 15th, 1892.

Of all that we have tried I like our standard best 58-lb. rail, top-corner radius, $\frac{7}{16}$ in.

My idea of a perfect rail has always been that they should be rolled rights and lefts, the outside top corner rounded only enough to take

off the sharp corner, the inside top-corner radius to be from $\frac{7}{16}$ to $\frac{9}{16}$ in., and inside of head to be $\frac{1}{16}$ in. out of vertical, the fullness being at the bottom of the rail. Yours truly,

BLAIR BURWELL, Jr.,
Chief Engineer.

THE NEW YORK, CHICAGO AND ST. LOUIS RAILROAD COMPANY.
CLEVELAND, O., September 16th, 1892.

We have been using for the last three years a 65-lb. rail, radius of top, 12 ins.; radius of top corner, $\frac{5}{16}$ in.; angle of side of head, 4°; radius of bottom corner of head, $\frac{1}{16}$ in.; height of rail, $4\frac{1}{4}$ ins.; width of base, $4\frac{1}{4}$ ins.; width of head, $2\frac{7}{16}$ ins.

So far this section has given better satisfaction than any we have used.

We have in track at present 5 100 tons of the 65-lb. rail with section as given above. Yours truly,

G. W. VAUGHN,
Division Engineer.

EVANSVILLE AND TERRE HAUTE RAILROAD COMPANY,
EVANSVILLE, IND., September 14th, 1892.

The rail we have used on both the Peoria, Decatur and Evansville and Evansville and Terre Haute roads since I have been connected with the system has for its surface radius 15 ins. and for the top corners $\frac{5}{16}$ in., the lower corner $\frac{3}{16}$ in. with an angle of 7° perpendicular deflection from the lower corner to the top corner.

This form has given me the best satisfaction and I believe for general use is near to what the standard should be. I am not in favor of extreme sharp corners nor perpendicular sides on the ball of the rail, from the fact that the fillet and shape of flanges in engine drivers or car wheels must eventually cut away the top part and wear the top corner of the rail down to a radius of at least $\frac{3}{16}$ in. This being true, I do not believe there would be anything gained in making rails with corners having a smaller radius than $\frac{3}{16}$ in. and a deflection of at least 4° perpendicular.

It is very desirable, of course, to secure as much rail surface as is possible, and while the rail is new a flat top will give what is desired, but it would certainly be depreciated very soon, as no wheel can be made without having sufficient fillet to insure its strength, for if the fillet was entirely taken out you would be continually having broken flanges. Yours truly,

T. A. ALLEN,
Chief Engineer.

FITCHBURG RAILROAD COMPANY,
FITCHBURG, MASS., September 16th, 1892.

I send you herewith two blue prints showing rails lately used by the Fitchburg Railroad Company. The 1891 pattern which we are now using has $\frac{3}{8}$-in. top-corner radius, which is the shortest we have.

All the rails laid between 1882 and 1891 have had a large corner radius, most of them about like the 76-lb. $4\frac{1}{2}$-in. high section, a blue print of which is enclosed. We have now in the track 7 737 tons of the $4\frac{3}{4}$-in. high 76-lb., with $\frac{3}{8}$-in. corner radius, and I do not know of any trouble arising from sharp flanges which could have been caused by this rail. I have noticed that on the old 76-lb. section the wheel flanges cut much faster into the rails on the outside of curves, than on the new 76-lb. section. Both these sections were rolled at the South Scranton Works, and the material is presumably the same. If I were to design a new rail for our use, I think I should use $\frac{1}{4}$-in. corner radius and straight sides. I have never expressed an opinion on this subject to your committee. Yours truly,

A. S. CHEEVER,
Chief Engineer.

WESTERN NEW YORK AND PENNSYLVANIA RAILROAD COMPANY,
BUFFALO, N. Y., September 23d, 1892.

We have no "sharp top-cornered rail sections" on our lines.

Our "standard section" is Pennsylvania Steel Company's No. 2, or C. P. & Co.'s section old No. 35, present No. 50; all practically the same as Cambria section No. 55, 67 lbs. per yard.

Our experience with this section has been satisfactory so far.

Very truly yours,
R. D. MCCREARY,
Chief Engineer.

TOLEDO, ST. LOUIS AND KANSAS CITY RAILROAD COMPANY,
TOLEDO, O., November 23d, 1892.

In the use of rails with $\frac{1}{4}$-in. top-corner radius, I have found that the inside top corners of such rails on curves wore away very rapidly, and, in doing so, made many sharp wheel flanges, especially on those with steel tires. After these corners had worn down to about $\frac{1}{2}$-in. radius, the wear became less rapid on both rails and wheel flanges. In such cases, the sharp corner is of short duration, and its wearing away is accompanied by corresponding wear on wheel flanges. My experience with such rails, and with rails with $\frac{5}{8}$-in. top-corner radius, has led me to the conclusion that the former are not desirable for roads having in their alignment many sharp curves.

I have put down about 12 000 tons of rail with $\frac{1}{4}$-in. top-corner radius.

A. L. MILLS,
Chief Engineer.

September 26th, 1892.

Answering your letter of the 1st of September, my experience in the use of rails with sharp top corners is limited to the section recommended by the Society some time ago, of which we have purchased and laid down this year 1 500 tons, 75 lbs., steel, $4\frac{3}{4}$ ins. high; radius top corners, $\frac{1}{4}$ in.; breadth of head, $2\frac{9}{16}$ ins. Since it was laid I have noted the process of wearing very closely, and especially for evidences of contact between the wheel flanges and the inside vertical face of the rail head, but so far the closest scrutiny fails to discover any evidence of it. The wheels tread squarely on the top face of the rail and not their flanges on the corner or side or vertical face as they do on rails having large round top-corner, and inclined side faces. In that particular, and in fact all others, the section now promises the best results, and I believe the sharp top corner of $\frac{1}{4}$ in. to be a decided advantage over a large radius. The locomotive engineers think they can make better speed over this rail, and that it is due to a better traction on account of its broad face. While that is true I think there is far greater benefit derived from the flange clearance of the side face of the rail head, because the effect of that contact continuously is like an applied brake to retard the train's movement.

Yours truly,

T. H. Perry,

Chief Engineer L. E. & W. R. R.

The Lake Shore and Michigan Southern Railway Company,
Cleveland, O., September 16th, 1892.

Replying to yours of 1st instant, I enclose blue print of the 65 and 70-lb. rail sections which we have been using since 1889.*

So far as the wear of the rail is concerned, these sections have proven satisfactory.

The amount of rail of these sections laid from 1889–92, inclusive, is as follows:

Year.	Tons, 65-lb.	Tons, 70-lb.	Total.
1889	13 022	2 015	15 037
1890	16 475	2 538	19 013
1891	21 494	2 498	23 992
1892	22 465	4 501	26 966
	73 456	11 552	85 008

Yours truly,

E. A. Handy,

Chief Engineer.

* These sections show radius of upper corner, $\frac{5}{16}$ in. Radius of head, 12 ins. Inclination of sides of head, 4°.

THE PENNSYLVANIA RAILROAD COMPANY,
PHILADELPHIA, June 4th, 1891.

E. T. D. MYERS, Esq.,
Genl. Supt. R. F. & P. R. R. Co., Richmond, Va.

DEAR SIR,—In answer to yours of the 3d instant, the $\frac{7}{16}$-in. radius on the corner of our 85-lb. rail was placed there as a compromise between the Engineer Department and the Motive Power Department. The Motive Power Department always insisted on a $\frac{5}{8}$-in. radius, while we would very much prefer to have only $\frac{1}{4}$-in. radius. My own preference is, however, a $\frac{1}{4}$-in. radius on the upper corner, and vertical sides, but I was overruled and adopted the 85-lb. section as a compromise. I think it is the best section that we have ever had, and I take pleasure in sending you a lithograph of it (Fig. 23, Plate LXXIII).

Respectfully,
WM. H. BROWN,
Chief Engineer.

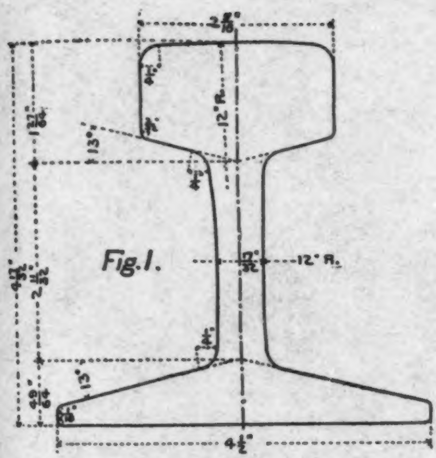


Fig. 1.

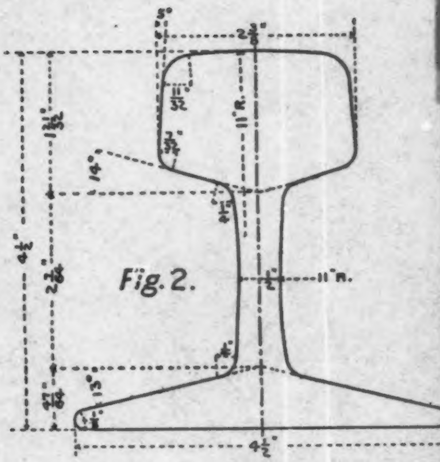


Fig. 2.

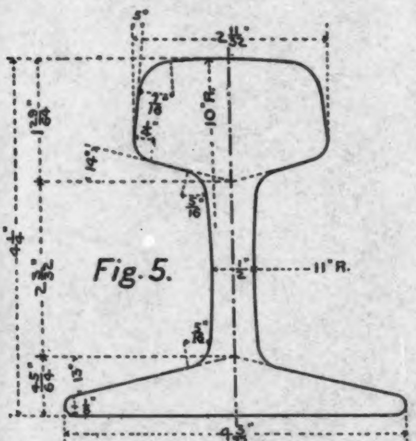


Fig. 5.

60 Lbs.

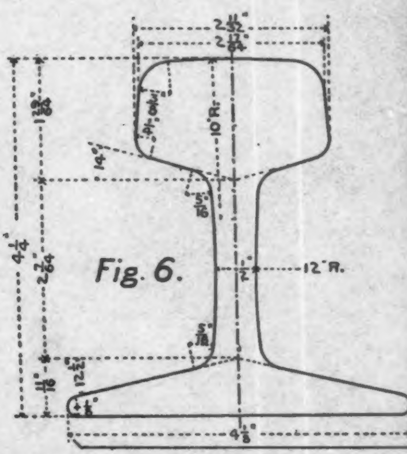
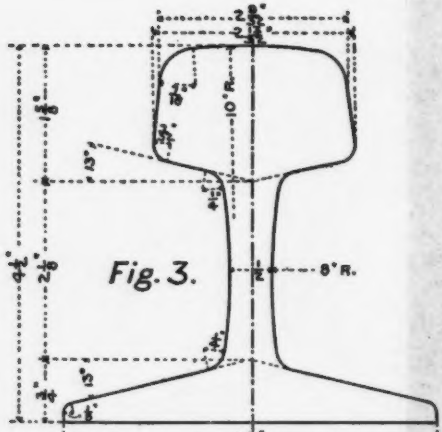
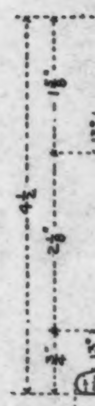
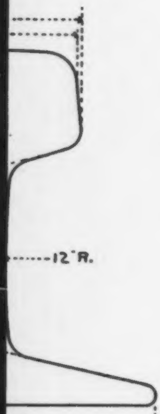


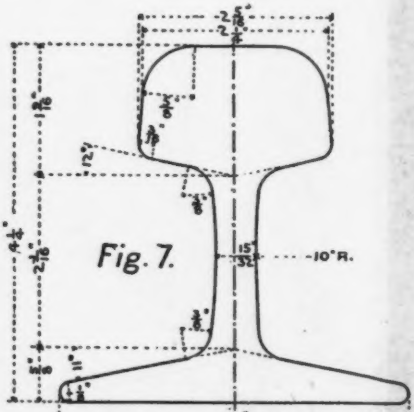
Fig. 6.

60 Lbs.









BS.

60 LBS.

PLATE LXXI.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XXVIII, No. 601.
APPENDIX TO REPORT ON STANDARD RAIL SECTIONS.

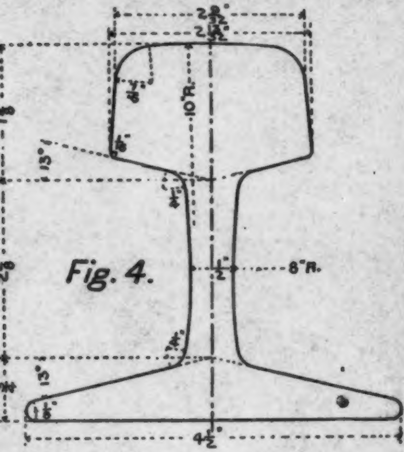


Fig. 4.

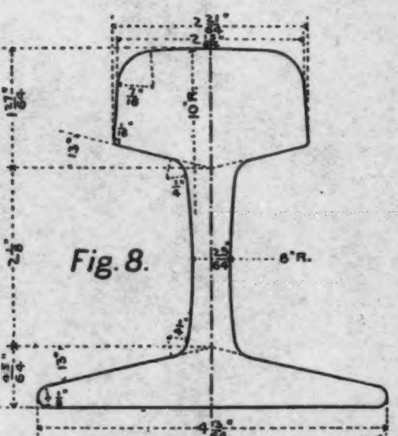
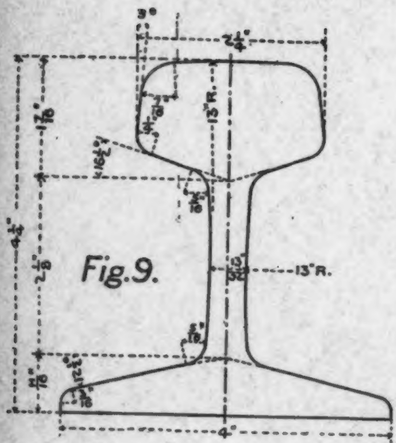
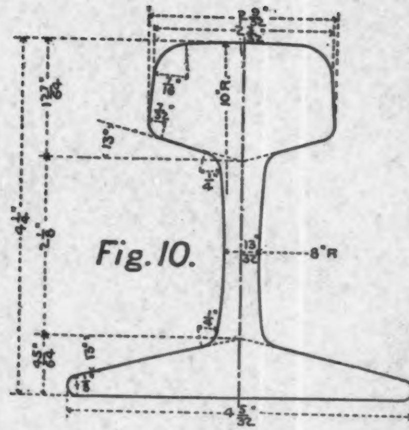


Fig. 8.

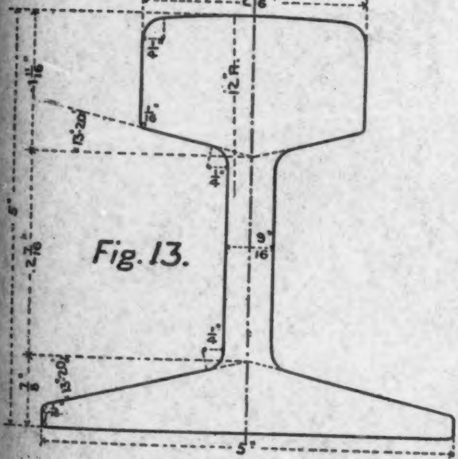
60 LBS.



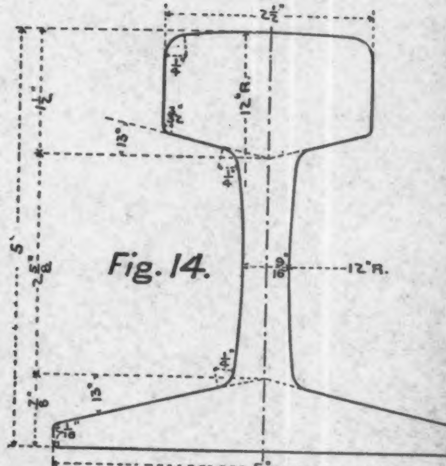
56 Lbs.



56 Lbs.

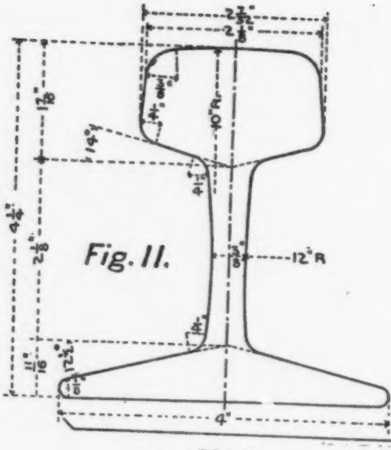


85 LBS.

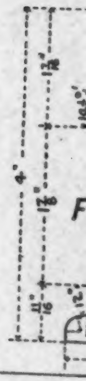


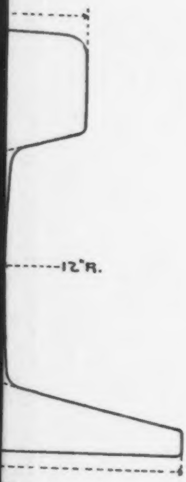
80 LBS.

BS.

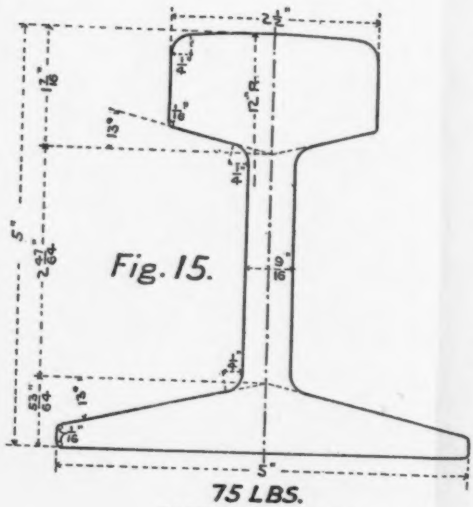


56 Lbs.





S.



75 LBS.

BOSTON & MAINE R.R.

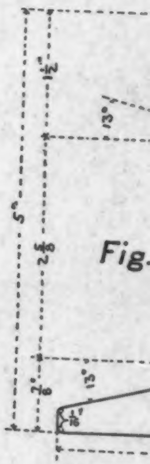


PLATE LXXII.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XXVIII, No. 601.
ENDIX TO REPORT ON STANDARD RAIL SECTIONS.

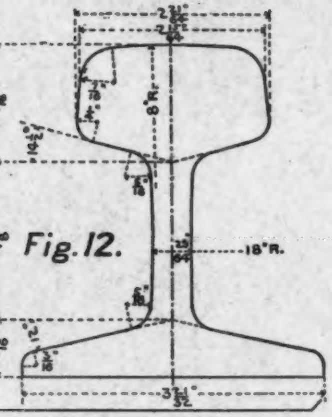


Fig. 12.

56 LBS.

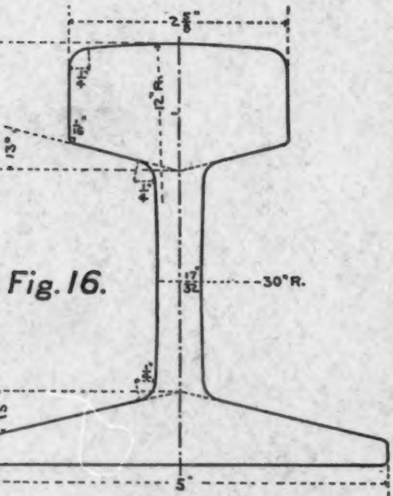


Fig. 16.

80 LBS.
N. Y. L. E. & W. R. R.

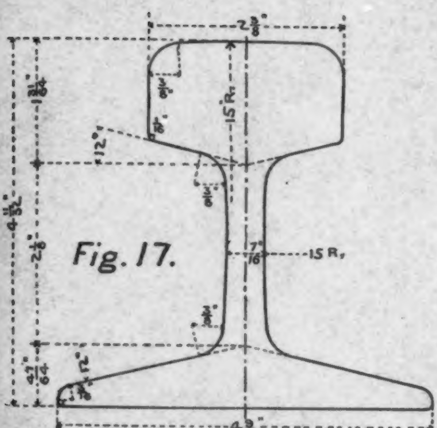


Fig. 17.

66 LBS.

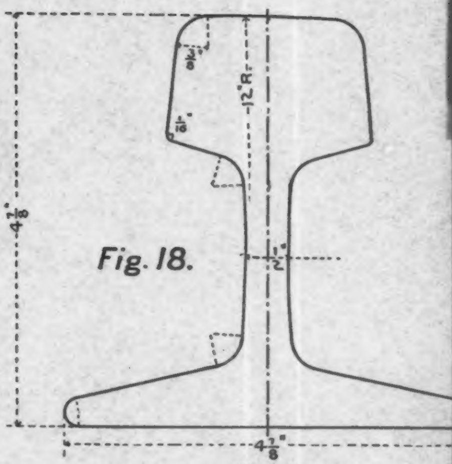


Fig. 18.

79 LBS.

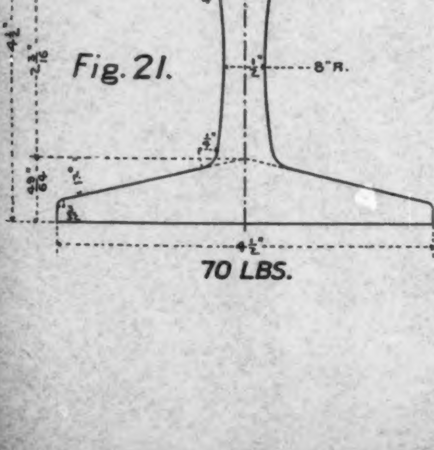


Fig. 21.

70 LBS.

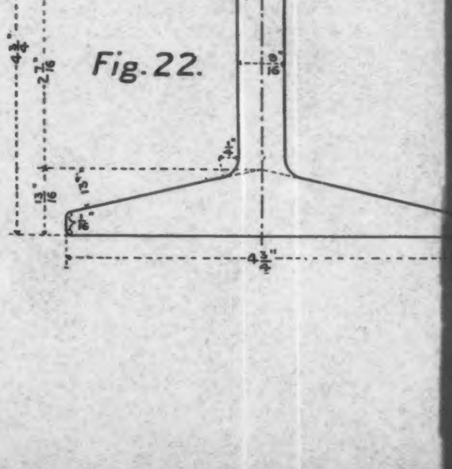
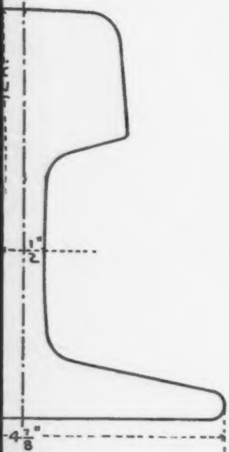


Fig. 22.

APPEND



9 LBS.

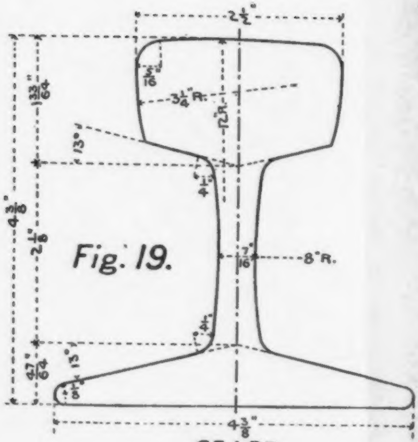


Fig. 19.

65 LBS.

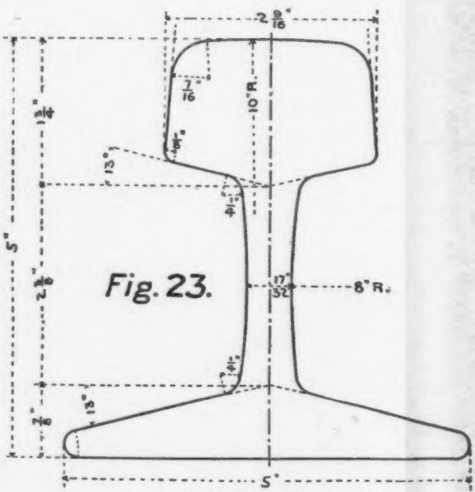


Fig. 23.

85 LBS

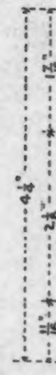


PLATE LXXIII.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XXVIII, No. 601.
[AP]PENDIX TO REPORT ON STANDARD RAIL SECTIONS.

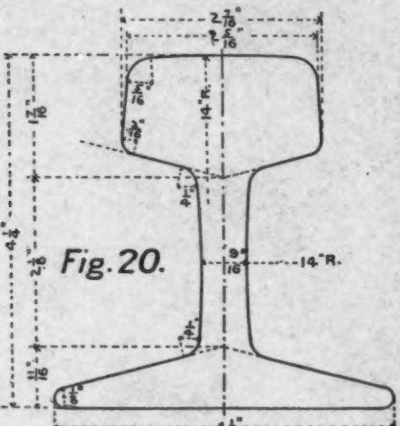


Fig. 20.

65 LBS.

PLATE LXXIV.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XXVIII, No. 601.
MONTFORT ON STANDARD RAIL SECTIONS.

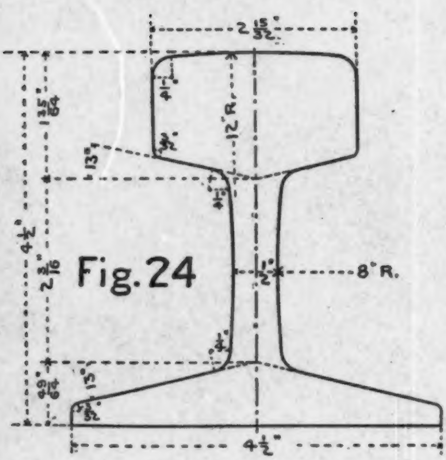


Fig. 24

70 LBS.

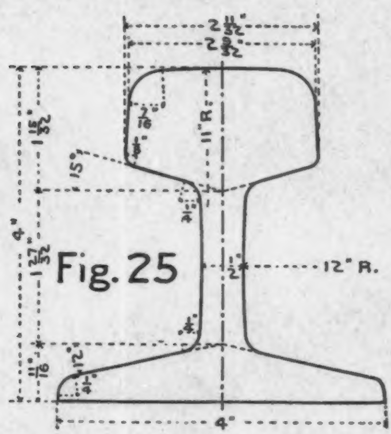
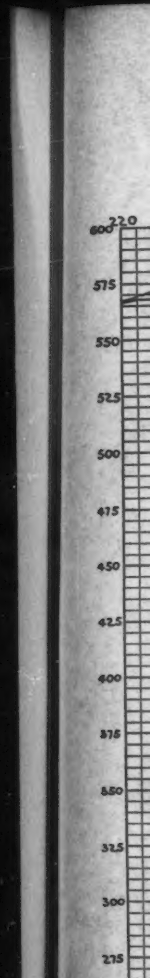
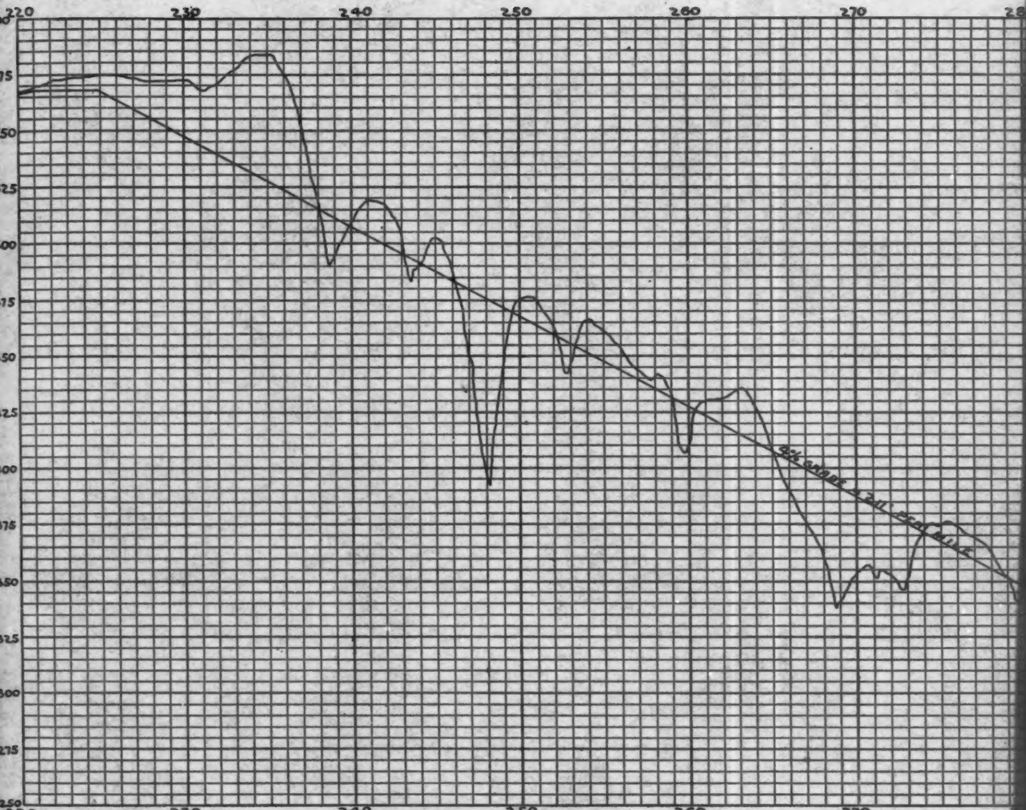


Fig. 25

58¼ LBS.


220
600
575
550
525
500
475
450
425
400
375
350
325
300
275
250
220
M.P. #19



NOTE.

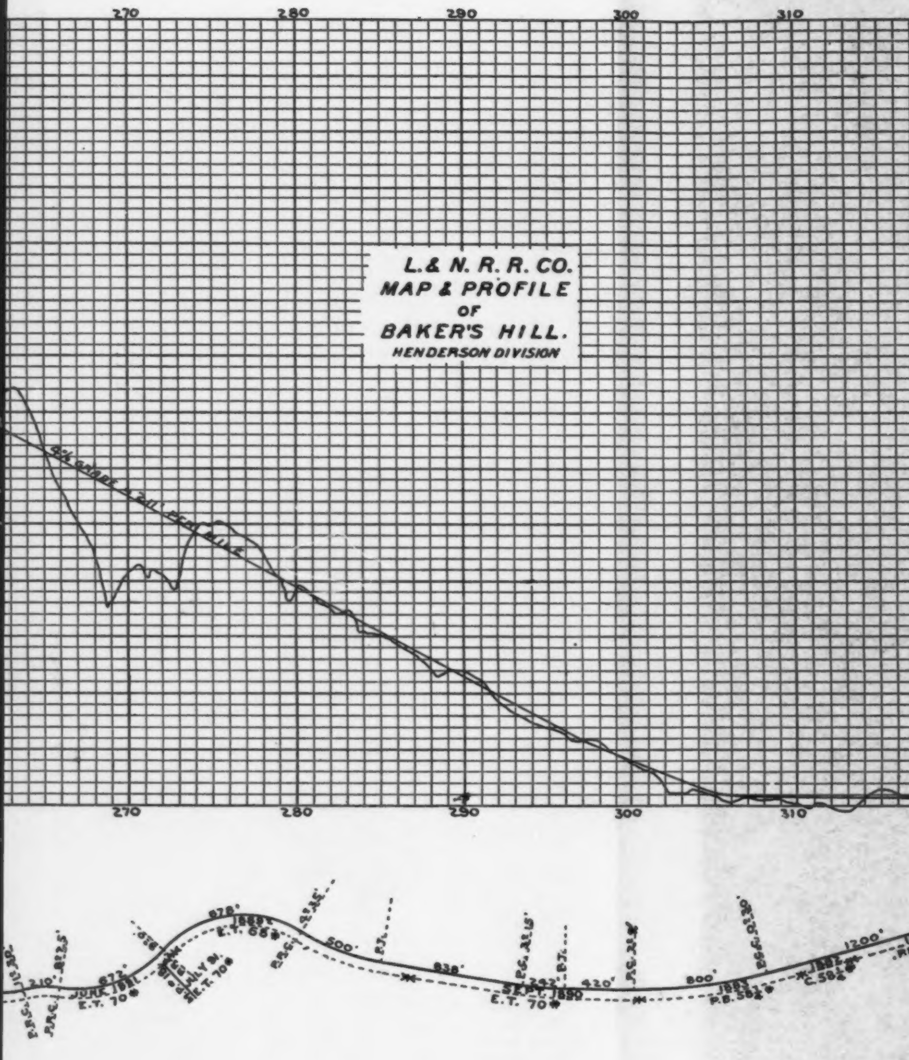
1892' C.70# INDICATES THAT THE RAIL EMBRACED BETWEEN THE ARROW POINTS WAS LAID IN THE FIRST HALF OF THE YEAR 1892, THAT IT WAS MADE BY THE "CAMBRIA IRON CO" & WEIGHS 70 LBS. PER YARD.

1889^2 INDICATES RAIL LAID IN THE SECOND HALF OF THE YEAR 1889.

E.T. INDICATES RAIL MADE BY THE EDGAR THOMPSON STEEL CO.

P.B. " " " " " PITTSBURGH BESSEMER STEEL CO.

PLATE LXXV.
TRANS. AM. SOC. CIV.
VOL. XXVIII, No.
MONTFORT ON STANDARD



LXXV.
C. CIV. ENGRS.
I, No. 601.
OARD RAIL SECTIONS.

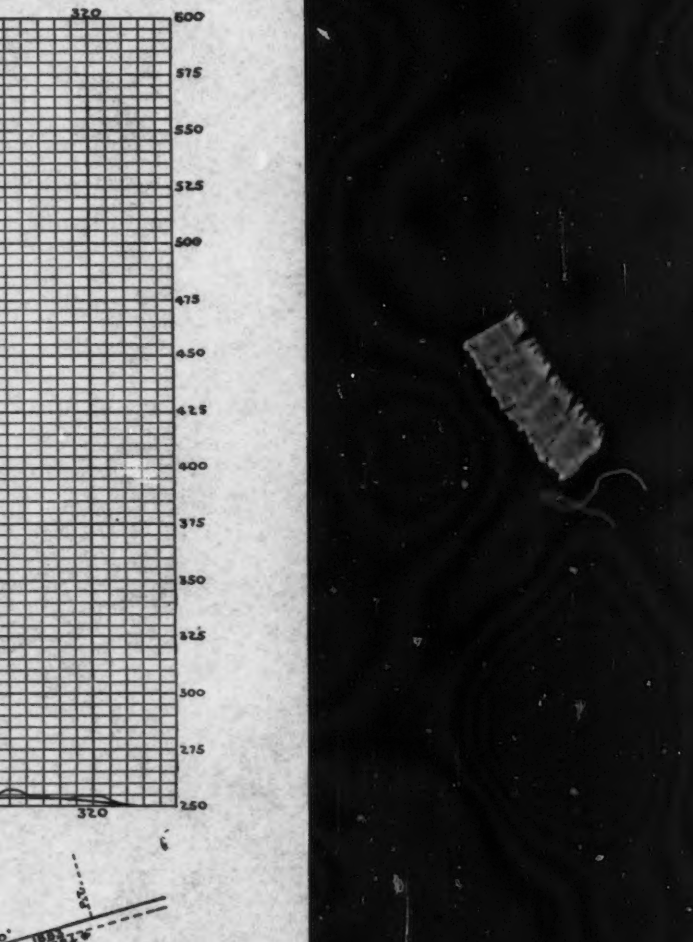
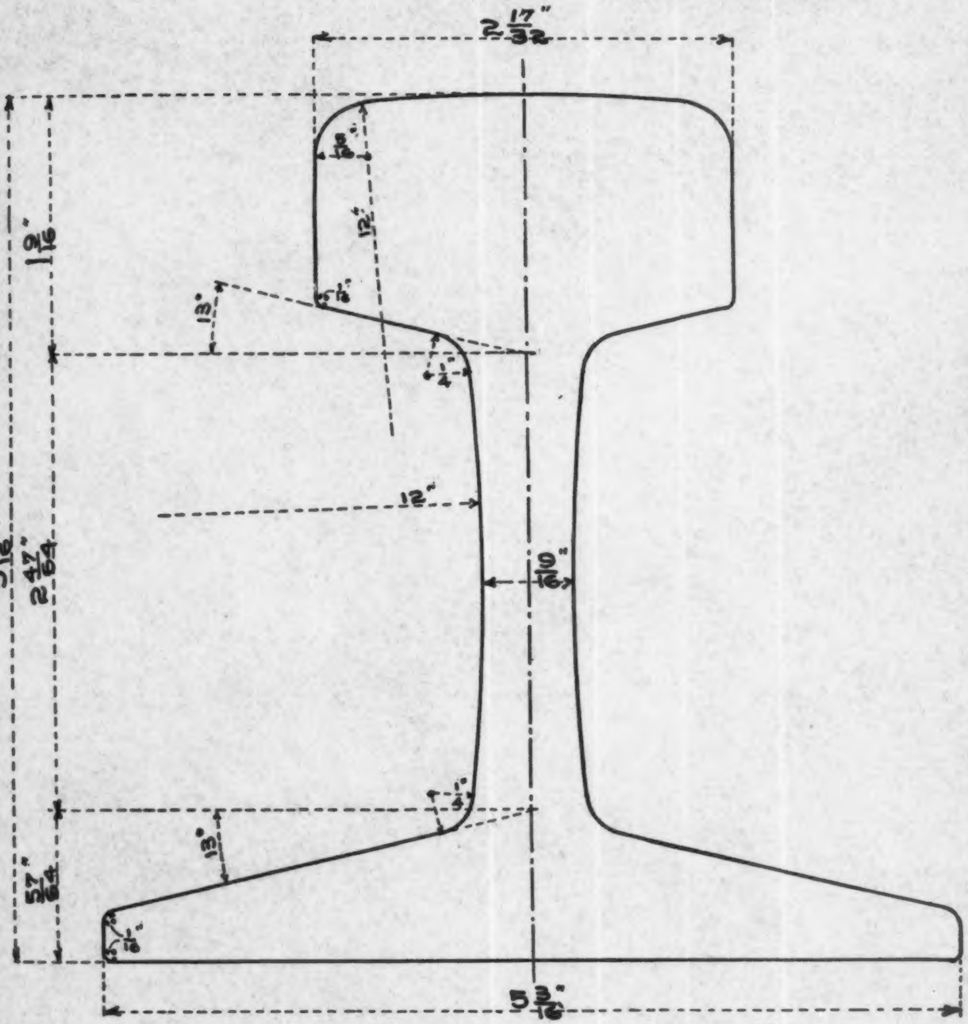
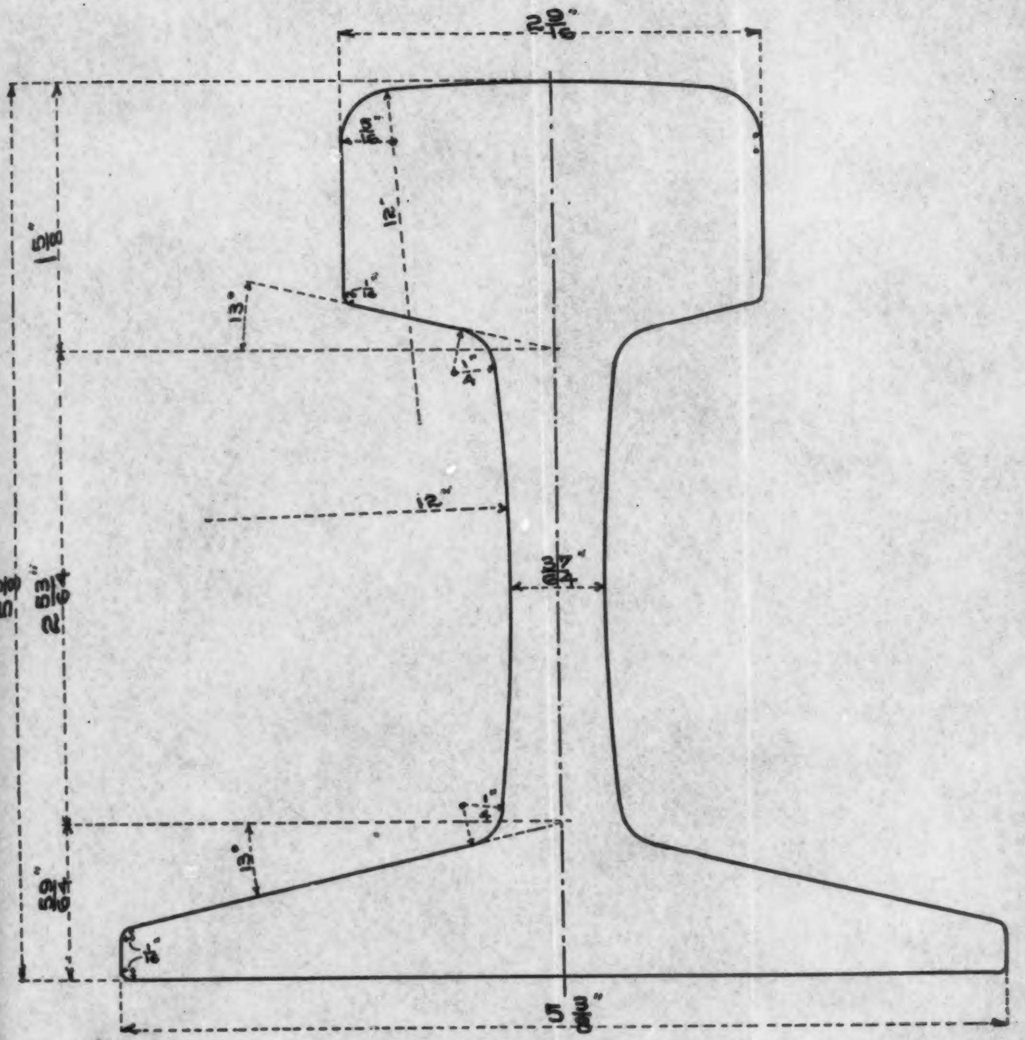


PLATE LXXVI.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XXVIII, No. 601.
MORISON ON STANDARD RAIL SECTIONS.



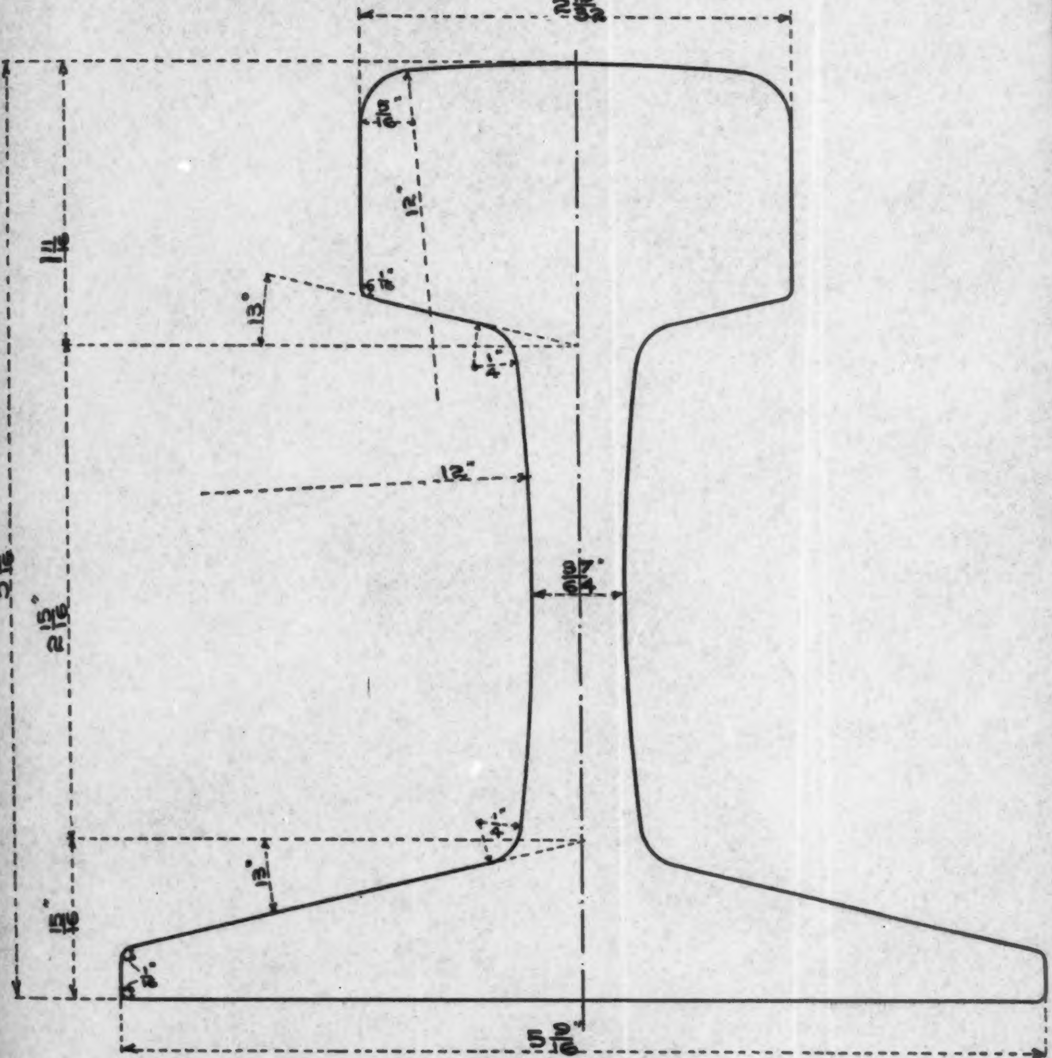
85 LBS.

PLATE LXXVII.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XXVIII, No. 601.
MORISON ON STANDARD RAIL SECTIONS.

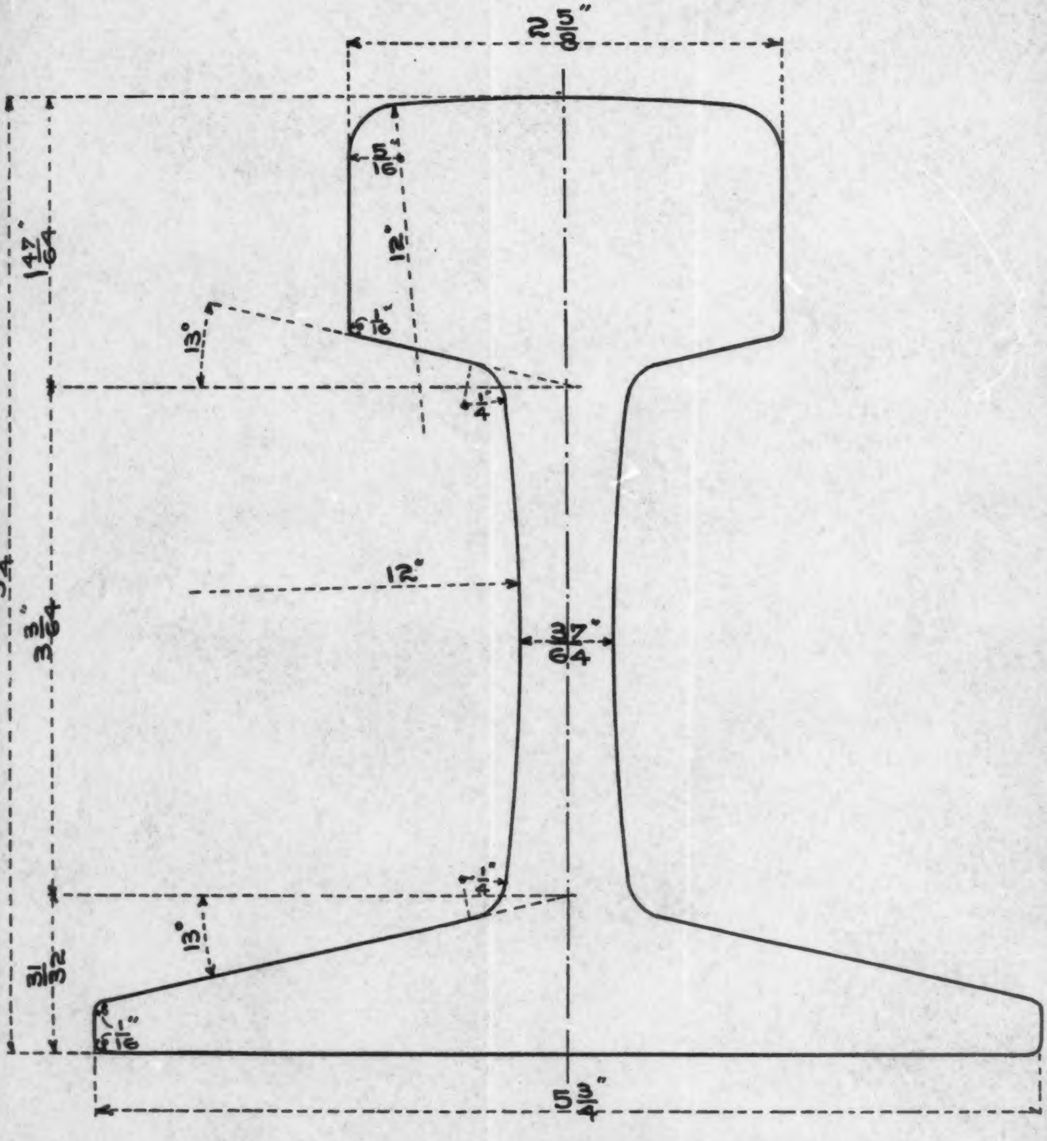


90 Lbs.

PLATE LXXVIII.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XXVIII, No. 601.
MORISON ON STANDARD RAIL SECTIONS.



95 Lbs.



100 Lbs.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

TRANSACTIONS.

602.
(Vol. XXVIII.—June, 1893.)

RIVER IMPROVEMENT—DISCUSSION ON PAPER No. 588.*

By CHARLES B. BRUSH, EDGAR B. GOSLING, W. R. HUTTON, J. J. R. CROES, JOHN BOGART, F. S. WASHBURN, W P. CRAIGHILL and H. D. WHITCOMB.

CHARLES B. BRUSH, Vice-President Am. Soc. C. E.—Mr. Chairman, on page 9 of this interesting paper I note this paragraph: "This increase in depth of channel, which is 7 ft. near Richmond, is almost exclusively in rock for 3 miles below the city limits, and although the larger part can be removed by dredging alone, the estimated cost of this section was more than half that of the entire project." I am not personally familiar with the apparatus that is used in dredging rock under such conditions, and if there is any member present who can describe it, I wish he would do so.

EDGAR B. GOSLING. Jun. Am. Soc. C. E.—I have seen such a dredge in use on the Suez Canal. It is composed of a series of chisels about 16 ft. long and about 8 x 8 ins., with chisel points; they drop about 7 ft., and break the rock in pieces, varying from small pieces up to $1\frac{1}{2}$

* "The Improvement of James River, Va.," by H. D. Whitcomb, M. Am. Soc C. E., Vol. XXVIII, p. 209.

cu.yds., which are picked up and deposited on the dredge, and then dumped.

In regard to the question of dredging causing a channel to be kept open, I think this can be seen in the Suez Canal, because there they cut through sand, and the channel is kept perfectly. In the center the depth of the Suez Canal is about 9 m., the sides have a ledge about 4½ m., and that channel retains its shape. When boats go through they have to lessen their speed, so as not to break the sand in, but the channel keeps its place. Of course, there are a great many currents, but it is not like a river.

In regard to the large dredge I mentioned, I think they dredged about 400 to 500 cu. m. per day. I should think it would be preferable to blasting.

W. R. HUTTON, M. Am. Soc. C. E.—It is believed that the dredges used on the James are strong dipper dredges. The recent Suez rock dredge (just referred to) is an endless chain dredge, with the rock-cutting rams or chisels arranged in series in front of the buckets. Similar single rock-cutting rams, with separate dredges, are in use on the Danube improvement, at and above the Iron Gate. Their weight is from 4 to 8½ tons. Similar chisels were used at Rock Island Rapids, on the upper Mississippi, in 1867, but the system had been applied in France 15 years before.

With regard to the maintenance of a dredged channel, there are many collateral circumstances which affect the result, and it is not always easy to discover them. I recall an attempt to dredge out a sand bar across the deep channel of a wide, shallow river. With a view to aid Nature, the engineer selected the shortest line between the proper depth curves as the point where Nature was making her effort to cut through the bar. But Nature had another force at work to maintain the bar, which was not taken into account, and the cut filled as fast as it was taken out.

* * * * * * * * *

The bar at Sandy Hook may be cited as a place where permanent results are obtained by dredging. Many projects were formed for deepening the channel over the bar by contraction work, some of them proposing jetties several miles in length. Finally, dredging was tried, and, contrary to general expectation, has proved entirely successful.

J. J. R. CROES, M. Am. Soc. C. E.—The statement made by Mr.

Hutton shows what I said in regard to the study of natural causes and working the way Nature works. The engineer in the Potomac River opposite Washington dredged out, neglecting certain current effects, and the channel filled up. Unless a study is made of the action of the particular river in the particular soil—because you cannot calculate that from general principles, you have got to know the local circumstances well—if a study is made of the action of the same river in that kind of soil, and you can dredge out a channel as Nature has done it in other places, I do not see why it should not remain. The remarks of the writer in the early part of the paper. which I have just had an opportunity of looking over a little more carefully, certainly show that this paper is an exceedingly valuable one in showing the effects of a plan not carefully studied. "Nothing but a general plan can be made in advance of the determination of the action of the river." I do not know that I am prepared to endorse that statement entirely. Provided sufficient time is given and sufficient appropriations are made by Congress, and a proper study made in advance, the improvement of the James must be more or less tentative to secure the best results, and that is the case, unquestionably. Any experiments must be more or less tentative, and unless Congress or the governing body can be induced to make sufficient appropriations to allow for proper examinations to be made before the works are undertaken, all works on our rivers must be tentative only, and not produce the effects at once which are desired.

Mr. Brush.—Mr. Chairman, speaking of dredging, there are numerous cases where dredging has to be resorted to, even if it does not produce a permanent effect, and the most obvious case probably is that of the Hudson River. The silt in the Hudson, on both the New Jersey and the New York shores, accumulates very rapidly. The piers have to be dredged out at least once and sometimes twice a year. The depth dredged ranges from 4 to 8 ft. per year, if you dredge below the natural bed of the river. This silt, however, that forms the bed of the river, makes the most magnificent bottom that we could have; in case our slips silt up and vessels are grounded, they are not injured. In a rock or sand formation it is a serious matter for a vessel to ground. Silt is not so objectionable. But this silt has to be continually dredged, in order to keep our slips clear.

Mr. Croes.—The remarks of Mr. Brush are very interesting, but

they do not controvert the general question at all. In the improvement of a river, you want to improve the natural conditions in such a way that the channel, in the natural state of the waters around it, will not be filled up and the sediment allowed to gain lodgment, and which will be sufficient to carry vessels. In the cases mentioned by Mr. Brush there is no comparison at all between them, because there dredging is necessary all the time, according to the natural conditions, and there is no possibility of doing permanent good by dredging in that case; it is very different from the channel of a river.

John Bogart, M. Am. Soc. C. E.—Mr. President, I think that we can congratulate ourselves upon having a paper like this from the member of the Society who has been so long connected with this important work. It is, as I have been able to apprehend its scope from hearing it read by the Secretary (I have not had an opportunity of reading it before), an excellent description of work actually performed; a clear and concise statement of results obtained in the improvement of one of our most important rivers. It is a sequel, as stated by the writer, to a more extended paper given us by Colonel Craighill, which described minutely the improvement of a number of the rivers upon the Atlantic Coast, and in that paper Colonel Craighill referred to the James with the expression of a hope that the engineer in immediate charge would give a more detailed paper, and this is, I suppose, the result. The descriptions of the improvements made under the direction of the Corps of Engineers of the United States Army are to be found in the Reports of the Chief of Engineers; but these reports are not seen by many civil engineers, and therefore the publication in the *Transactions* of the Society of a paper of this character is of great value. The writer certainly develops, from actual experience and observation, many important points with reference to the treatment of a river of the character of the James, and, it seems to me, no fact is more clearly brought out than that the rule to be followed in the improvement of rivers is only to be deduced from thorough study of the laws indicated by Nature's conditions in each special case.

F. S. Washburn, M. Am. Soc. C. E.—I judge, from Mr. Croes' remarks, that his objection to a tentative method is based upon his belief that calculations alone are sufficient to determine the proper method for treating a stream like the James River. The very basis for calculations in such a case as the one treated of in this paper,

must be the result of tentative methods, and the paper bears evidence throughout that experimentation and calculation were carried on coincidently. It is a problem of currents, their causes and their effects. The stream is very tortuous, and the necessary cut-offs at various points give rise to new problems and conditions down stream, whose elements no mere calculation could anticipate. The equation would be an unsolvable one.

Mr. Croes finds a dangerous tendency on the part of the author to be elementary, and to absorb the time of the Society in the unnecessary cautioning of its learned members against ignorant dredging. In the third sheet of illustrations, following statement "D," are shown three different contractions of the stream at three different periods, 1877, 1880 and 1888, each with its resultant depth. This sheet is characteristic of the whole teaching of the paper, that dredging without some artificial means of fixing the width of current is useless, and dredging with some artificial means of maintaining the proper width for the desired depth and velocity is successful.

W. P. Craighill, M. Am. Soc. C. E.—This paper gives many interesting facts concerning the James River. The work has progressed very satisfactorily since the date of the paper printed in 1888, to which Mr. Whitcomb refers. The improvement has been a successful one, which is a great gratification to those who have been responsible for methods and results. There has sometimes been complaint that results have not been reached as speedily as desired, and thereupon fault has been found with the methods. The slowness as to results has been due to the want of money to push the work, and for this the engineers have not been responsible. Moreover, as Mr. Whitcomb remarks, "the scope of the work has been enlarged by law," which means that while a certain approved plan was in process of execution and was well advanced, viz., to give a depth of 15 ft. at low water to the city of Richmond, Congress, without recommendation from the engineers, and under some unusual and unknown influence, directed that the project should thereafter look to obtaining a depth of 22 ft. at low water.

This meant, of course, a much greater amount of work, and involved such changes as to render worthless, or nearly so, much that had already been done. But the directions of Congress have been loyally carried out as far as possible. What a great increase of depth was thus sought for will appear when it is noted that on some of the

worst shoals below Richmond where the improvement began in 1870 there were only 7 ft. at low water.

Many people suppose that in any river any desired depth of channel can be obtained. It is perhaps true that almost anything is possible to the engineer if he have an ample supply of money and time. But many things that are possible are not expedient. The natural conditions of a river fix the depth of channel it is reasonable to obtain and to maintain, considering the expense of the work and the needs of commerce present and prospective.

For a river like the James the operations necessary for its improvement are dredging, rock-excavation, and the contraction and regulation of the water-way by training walls and wing dams. The removal of rock under water is a very expensive and tedious work and the expense increases with the depth. Unfortunately the development of rock is very great near Richmond. There is one comfort, however, about the removal of rock from a channel. It does not re-appear, as so often do the sand and mud which are dredged. But the moving sand or silt sometimes is deposited by the river in a channel excavated in the solid rock, and must then as elsewhere be removed by the dredge or by works of contraction designed to increase the velocity and prevent deposition.

When the material to be removed to give increased depth is such as can be scoured by a current with an increased velocity, two methods suggest themselves. The obstruction may be rapidly removed by the dredge and the needs of commerce be quickly satisfied, or works of contraction may be used, to give the necessary increase of velocity and consequent scour. The latter is generally a much slower process, but if the dredge is depended upon alone, it is usually necessary to do its work over and over again. If money be abundant and time presses, the best arrangement is to dredge the needed channel and at the same time put in works of contraction to maintain the dredged channel. It is not to be expected, however, except in very rare cases, that an artificial channel of any kind is to remain in good condition unless looked after and repaired. This need for repairs is not a peculiarity of works of river and harbor improvement, but is equally applicable to railways, streets, roads, etc. If neglected, their expense increases, and to execute them with money intended to be applied to the original improvement, as often happens, tends to increase its apparent cost.

As a rule, in the improvement of rivers and harbors by the United States, and this is true of the James, the use of the dredge is specially prominent in the earlier stages, in order to attain results quickly, navigators and commercial men being unwilling to wait for the slower action of regulating works. If the works of regulation are put in as money allows, the success of the improvement is shown by the continually decreasing appearance of the dredge. And this has been the case on the James. Another test of the success of the work on the James may be seen in the following table:

Statement of Depths in James River Available for Navigation at Low Tide:

	1870. Feet.	1893. Feet.
From the city to Richmond Bar	7.0	13.8
Over Richmond Bar and Randolph Flat	7.0	15.0
From Randolph Flat over Warwick Bar	12.4	18.0
From Warwick Bar to City Point (Trent's Reach in 1870*)	7.0	15.5
From City Point to the sea	14.8	17.0

The present available depth for navigation at full tide is 18½ ft. from the sea to Richmond Bar, and 16½ ft. thence to the city limits of Richmond.

The mistake is sometimes made on the part of those interested in the commerce of a port of demanding a greater depth of channel than the physical characteristics of the river justify the engineer in trying for at first and in attempting to maintain. Great depth can only be had by much dredging or by great contraction, or a combination of both. If the dredges are used alone, they must be always at work at much expense and are themselves a serious obstruction to navigation. If works of contraction are resorted to, the channel must be made proportionally narrow, and thus navigation is impeded. The best plan therefore is for cities on small streams not to be too desirous of very great depths, but to be satisfied with the more moderate depth consistent with a width appropriate to the river itself.

H. D. Whitcomb, M. Am. Soc. C. E.—The rock to be removed was described in Colonel Craighill's paper as follows: "Granitic, partly in

* Trent's Reach is now avoided by Dutch Gap Cut-Off.

beds and ledges and partly in detached boulders. There is much of it which has never been compacted, or has become disintegrated, and is so soft as to be readily removed by a strong dredge."

The disintegrated rock, as I prefer to term it, is granulated and resembles in appearance a very dark granite. It is friable but does not yield readily to the current. It is said to be more troublesome to drill and blast than solid granite. Attempts to economize its excavation by blasting have not been successful. The ordinary dipper dredges are employed.

There are hard strata found in it with the softer recurring below. The strata vary from an inch to three or more feet, and the thinner are often a very pure quartz. The thicker are gneiss. All the submerged ledges of solid rock have more or less of this soft rock on them.

The chisels referred to by Messrs. Hutton and Gosling might be used with advantage in aid of dredging, and if the machine would break up the solid rock in the James, its use would be very acceptable.

A chisel something like that described, but not so heavy or elaborate, was used in the removal of some dangerous points on Rocketts Reef, at Richmond, with success, nearly 40 years since. I think it was worked in the gin of an ordinary pile driver.

The prices paid for excavating the soft rock have been from 40 cents to $2, and for solid rock from $5 to $8 per cubic yard.

Noticing the comments of Mr. Croes, it is proper to say that the condition of the James in 1870, when its improvement was begun by the United States, was not a natural one for 20 miles below Richmond. The channel had been blocked and changed by obstructions and military bridges for nearly 10 years, and although Richmond had opened a narrow way around or through these, a more complete removal was required by commerce to open a channel no better than that existing before the obstructions were placed and with the least possible delay. It was not the time for an extended survey. This was made, however, in 1874, and as soon as practicable afterward, a general plan and estimate was made for the older project of 15 ft. This was nearly completed in 1882. A general plan and estimate for the later project followed an elaborate survey in 1882, which included borings in the river bed where there were less than 25 ft. of water. This plan is being

carried out as fast as means are provided, and about 16% of the estimated cost of the new project had been expended when the paper under discussion was written.

While the engineer officer in charge will not claim to have seen the end from the beginning, he has seen a steady progress towards it; and if some expenditures have not secured permanent results, none of them, so far as I am informed, were made unless dictated by the imperative needs of commerce or other sufficient reasons. But Colonel Craighill has fully covered this ground in discussing the paper.

The article under discussion is a contribution of facts as the writer viewed them, and was submitted with an expectation of criticism, and a hope that he would thereby gain valuable information from members who have had experience on similar work. There was no expectation of imparting information to such persons, still less to condemn dredging where it was proper. He stated on page 26 of his paper that dredging alone was contracted for in improving the channel below City Point. That part of the James is rather an estuary, where fluvial currents have become insignificant compared with those due to the tides. The waterway is very wide and available for light-draught vessels outside the channel; and regulating works would in some cases interfere seriously with such vessels under sail, as well as with the local traffic. Regulation was also thought more expensive than maintenance by repeated dredging in this part of the river, and was not included in the plan except for a shoal near Jamestown. The deterioration of the channels which were dredged to 18 ft. in depth in 1881, amounts to about $8 300 at this date, and they will be redredged. If experience shows that regulation is also needed, or would be more economical for the enlarged project of 22 ft., I have no doubt it will be introduced wherever it can be, with due regard to other conditions.

Between the rock near Richmond and City Point, the shoals and shallow reaches between them are of recent alluvium, to the depth of the project at least in nearly every case. This was ascertained by the borings. Where this is not the case, dredging in part is generally needed. The river banks, in the main, are firm, yielding but slowly where exposed to the current; so that the lines of flow are constant in direction, varying somewhat with the discharge, but constant taking a few years together. There is an older bed below the alluvium, perhaps of similar material to the higher banks or bluffs.

The alluvium, a more or less muddy sand, is to a certain depth constantly in motion, with a preponderance down stream varying with the strength of the currents, fluvial and tidal, with a greater movement in freshets. The direction of the currents, and other conditions, being practically constant, the river bed with its shoals and reaches has been remarkably permanent in profile and section for 40 years at least, where undisturbed, and could not be otherwise by natural law; although formed and maintained in a constantly moving mass of silt. In the bends there is a slope toward the concave bank, depending perhaps on the radius of the flow; at the middle of the cross-overs the bed is practically level, especially so where tidal currents are weak. Dredging under such conditions is a temporary expedient whether the whole width is dredged over or a channel only sufficient for navigation is cut. It is an enlargement of area not needed by the flow, and the river will restore the old section to the condition required by nature's laws at that point.

This is recognized and concisely stated by Mr. Washburn in his remarks.

If the surface is contracted, the area is thereby reduced and the river will take a deeper section to regain it. If the direction of the current is not materially changed by the regulation, and it is not for freshets overtopping the works, the bottom slopes and levels will be reformed at a greater depth, corresponding with the amount of the contraction. This requires time, depending on the discharge of the river.

If to hasten the process dredging is done as "Nature has done it in other places," it must include a prism of about the whole width between the works of a depth which will make the area of the prison that of the contraction. Its bed must be substantially parallel in cross-section to the former bed. This is what the river has taught, as numerous sections like that submitted with the paper are at hand to show. This is not the way dredging is usually done; but a deep cut of the width required for navigation is made, perhaps one-fourth the width between the works on this river. Such a cut will be obliterated, but it will hasten the deepening which Nature would have made at no expense, and might have made in a few days of a great freshet.

The "soils" in the bed of the river, in this alluvium, vary only in

being of muddier and finer particles the farther they are from the head of tide, and are all "material readily moved by the current."

The shallower reaches between the shoals proper on this river, if in alluvium, have too much surface width; the shoals are at cross-overs; both require contraction to make them deeper than Nature has made them. If contraction is properly made, it is sufficient without dredging. "Tentative" work is sometimes needed for us to find out what is proper, but the general rule is to make the width such as to produce the width and depth of channel required in a river-bed, which must be parallel to the old and have the same area at low tide. The practice is to add a percentage to this width, expecting that a larger area will be maintained in the improved river, since results have indicated that, or perhaps only that the area should be measured at a level somewhat above low tide. An increase over the projected depth is of less importance than the maintenance of the greatest width practicable on this part of the James.

The more distant from the head of tide the stronger the tidal and weaker the fluvial currents appear to be on this river, and no natural section will suit as a model for a section distant from it.

It may not be out of place to say that a freshet which occurred in May, since the presentation of the paper, rising to 17 ft., scoured 104 000 cu. yds. from between the works from Richmond Bar to Falling Creek. The limiting depth of channel on the stretch of $3\frac{1}{2}$ ins. below the bar was increased from 16.4 to 18 ft., with an increase in depth and area at almost every section measured. The bar has small areas of rock at a depth of 16 ft. in process of removal.

This action was mainly due to repairs and extensions of the regulation works, which were not completed at the time of the freshet, except on the lowest of the four shoals included between the works mentioned.

I beg to thank the members who have taken part in the discussion of the paper.

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COST OF OPERATING CABLE RAILWAYS.—DISCUSSION ON PAPER No. 590.*

By P. F. BRENDLINGER, O. F. NICHOLS, CHAS. B. BRUSH, JOSEPH T. DODGE, T. C. CLARKE, E. E. R. TRATMAN, AND D. BONTECOU.

P. F. BRENDLINGER, M. Am. Soc. C. E.—It is a surprise to me, and no doubt to others, that the cost of a cable railroad is so terribly expensive. It would be exceedingly interesting to know the relative average cost of trolley and horse railroad systems. I know the trolley or electric system must be very much cheaper, or else it would not be coming in such general use. As an instance, take the city of Philadelphia, Pa., where cable cars have been used for a number of years on a number of streets, which are all to be replaced by the trolley electric system. Another feature of the cable system is the cars cannot run faster than the speed of the cable, which travels at rates from 6 to 10 miles an hour; so if a car is delayed for any length of time, it cannot make up the lost time. The trolley cars can make up lost time

* "Notes on Operating Cable Railways," by D. Bontecou, M. Am. Soc. C. E., Vol. XXVIII, p. 250.

at will. As an illustration, in my home, the City of Yonkers, N. Y., we have a trolley system; the speed of the cars was fixed by ordinance at 7 miles an hour, then changed to 10 miles an hour. It is a common occurrence when cars are detained that they catch up to the schedule again by bursts of speed from 15 to 20 miles an hour. This trolley system is a wonderful change from the old horse-car system. The speed of the cars varied from 2 to 4 miles an hour, in fact it was so slow that people got disgusted and would rather walk; the result was the sheriff and receiver soon gobbled it up, when by reorganization a trolley system was established. Result—the cars are well filled and the road is paying. Speed, with comfort and safety, is what we want, and we must have it.

O. F. Nichols, M. Am. Soc. C. E.—This line would seem in many respects not one that could well be compared with electric or horse lines in other parts of the country. I don't know how long it has been in operation, but the number of passengers they are carrying is relatively very small, and this plays a very important part in the economical operation of a railroad. From the figures given here, the ratio of receipts to expenditures is prejudicial to this line, and prevents it from making a good showing for cable railways. If we look at the gross earnings and assume that the line is only about 8½ miles long, comparing this with the same length of line in other places, the gross receipts should be in the neighborhood of $266 000, while the operating expenses are here $195 241 73. The operating expenses would be about 75½% of the gross earnings, which is very high, and probably due to the fact that very few passengers were carried. If we allow 6% on the cost of construction for fixed charges, the operating expenses are practically equivalent to the gross receipts, so this line would seem to be a very expensive line to operate, because the number of passengers carried is so small. I suppose there must have been some reason other than the simple carrying of passengers which necessitated the construction of this kind of a line. I think it should have been operated by horses, unless there was some other predominating necessity. In more populous districts, the number of passengers and the gross receipts have become so large that the operating expenses can be very heavy and still be consistent with economical operation.

Charles B. Brush, M. Am. Soc. C. E.—On April 27th, 1885, The

North Hudson County Railway Company commenced to operate its elevated road in New Jersey, from the Hoboken Ferry to the brow of the Palisades, a length of 5 820 ft., with a cable. The life of the cable on this elevated road ranged from 6 to 16 months, the average was about 12 months. This elevated road is the terminus of several horse-car lines that unite on the brow of the hill. The maximum grade on this elevated road is 5% for 2 100 ft.

In 1891, an extension of this elevated road was made on the top of the Palisades for a distance of 5 280 ft. On June 22d, 1892, the railway company commenced to operate this extension of the elevated road with electricity on the overhead trolley system. This system had never been previously attempted on an elevated road, but it worked so successfully that on November 6, 1892, the company commenced to operate the original portion of the elevated road with electricity except during commission hours.

It may be of interest to state here that the elevated structure in itself forms the return circuit, the rails being bonded in the customary way, and these bonded wires connected with the iron-work of the structure. The bottoms of the posts are fixed in large, heavy castings resting on masonry foundations, and as these castings are thoroughly covered with Portland cement, it was thought best to put in heavy ground-plates at suitable intervals, in order to insure the proper grounding of the current.

On February 22d, 1893, the company discarded the cable entirely, and since that time it has operated both of these elevated roads by electricity, on the trolley system.

The operation of the road by electricity has given very satisfactory results. While the cars are not so large as those used with the cable, they can be run at very much greater speed and with shorter intervals of time. The stops at the stations along the line can be made with greater facility, and the speed of the car is always under perfect control.

What Mr. Clarke has stated in relation to other roads has been found true on this road, namely, that substituting electricity for a motive power and running over the line numerous, well-lighted and quick-running cars, is popular, and increases travel.

The cable cars used on this elevated road were 48 ft. long, weighed 25 000 lbs. empty and 40 000 lbs. loaded, and were carried by two four-

wheel trucks with steel-tire paper wheels, the wheel-base of each truck being 5 ft. The electric cars now running on the road are 34 ft. long, equipped with two 25-H. P. motors, the total weight being 18 000 lbs. empty and 23 000 lbs. loaded. These cars are carried by two maximum traction pivotal trucks, the wheel-base of each truck being 4 ft.

Locomotive engines have been used on this elevated road for night service during very light travel, and in cases of emergency when the cable plant was out of commission. These locomotives weigh 19 tons on a wheel-base of 7 ft. During their service on this road they were not called upon to haul more than one loaded car. Some of these engines are now in use on another line belonging to The North Hudson County Railway Company, running from the West Shore Ferry to the Guttenberg race track. On this line, about 3 miles in length, they haul six loaded cars, each weighing 28 000 lbs.

Joseph T. Dodge, M. Am. Soc. C. E.—I wish to call attention to the field of each of these different modes of travel. The horse cars have widened the area which cities have covered; the steam railroads have brought in another part of the country in which people live while they do business in great cities; now here come in the electric cars, and they take away some of the business of the horse cars, and, to a certain distance, say 10 miles, under favorable conditions, they seriously encroach upon the business of the steam cars. That has been proven at St. Paul and Minneapolis. I know, as a matter of fact, that a large number of people travel between those two cities on the electric cars. It is the same way at Boston, where people come in from Malden by the electric cars. The electric cars, picking up passengers along the way, have an important influence upon travel. So the combined effect of these methods of travel seems to be to spread our cities over vaster areas than was possible a generation ago.

T. C. Clarke, M. Am. Soc. C. E.—Mr. President, there is one important point which has always to be considered in analyzing these different systems and comparing them together. The cost of motive power on a surface railway is only about one-half the total expense of running the line. I am speaking now of the cost exclusive of fixed charges on capital. The economy of cable over horse can only be confined to one-half of the expenditure. So far as the experience of the Chicago lines—the South Side and the West Side—the mileage is very great; they rank among the largest cable lines, and the mileage by

horse and by cable is not very different—they show the cost to be a little less by cable than by horse, but the difference is not so great as one would suppose. It is the same way in Boston. But the important point to investors is in the enormous increase of capacity of cable or electric lines over horse lines, in consequence of the great speed which they can attain as soon as they get out into the country where they can make speed. Of course horses cannot compete with this at all. For that reason the people much prefer to ride on them. They can run more frequent trains with a less number of cars. The fact is that the number of passengers per car increases very much as soon as the road is turned into a cable line from a horse line.

Any one at all familiar with Kansas City would see why the Kansas City lines are operated with cables. The streets of Kansas City are very hilly, and it would be impossible to run any lines at all without cables—by any other means except by cables—over those grades, and a great many of those lines have been built for the purpose of developing real estate. They have had that effect; they have brought property into the market which would not have come into the market in 50 years. The streets are built up with nice residences, and there is a general look of prosperity; and if you go off a few streets beyond where there are no street-car lines, there is no such evidence of prosperity. I think they introduced the cable for the same reason as in San Francisco, on account of the steep grades.

There is another reason why the electric cars take away business from the steam cars. That reason will be given you by anybody who lives on the line of both a steam and an electric road; they will tell you they always take the electric car, because "by the steam line if we miss a train we might have to wait twenty minutes or half an hour for another, but by the electric road if we miss one car another comes along in two or three minutes, so we always take that line."

E. E. Russell Tratman, Assoc. M. Am. Soc. C. E.—In the commencement of his paper, Mr. Bontecou says of cable railways in general that "the cost of first-rate construction is so large that a considerable volume of business is necessary, to produce a return on the investment." It has often occurred to me that it ought to be possible to design a simpler system of construction, with less excavation and concrete, which would make cable traction available for lines with a less volume of business, but on which the advantages of the cable system

are desirable for reasons of grades, etc. Analyzing Mr. Bontecou's statements of cost of two roads, I find that the items of underground obstructions, substructure, track and line machinery and paving represent about \$117 445 and \$117 295 per mile out of a total cost of \$223 184 and \$239 240 per mile, including (as shown by the paper) equipment, cable, power plant, engineering and legal expenses, interest, etc.

A shallow-conduit cable railway was built, I believe, at Butte City, Mont., about two years ago by the Vogel Cable Construction Company, of New York. The conduit was designed by Mr. George S. Morison, and consisted of two Z bars riveted to a base plate and having riveted braces or yokes at intervals, the yokes not extending to the rails. The conduit was about 10 ins. deep and 5 ins. wide, and rested upon the wooden cross-ties carrying the rails. The sheaves were in pockets between the ties. Of course, a special grip was necessary, the Vogel grip being used in this case.

Another shallow-conduit system has iron yokes, shallow in the middle where the iron conduit is bolted to them, and higher at the ends to carry the track rails. The conduit is oval, about 12 ins. deep and 10 ins. wide, and the sheaves are in iron pockets between the yokes, and requiring no deeper excavation. The total depth from surface of paving to bottom of concrete level is 21 ins., while with the ordinary system it is generally about 36 ins. and 48 ins. at wheel pits. Of course, heavy construction is admissible for city lines with heavy traffic, but I think a lighter construction might be adopted in many other cases, to make cable traction more generally applicable.

D. Bontecou, M. Am. Soc. C. E.—It was the design of the paper to discuss only the cost of construction and operation, and to emphasize the fact that under the conditions of city travel and street regulations a good service could be given by a cable road at very small cost per car-mile. In this respect I can see no reason why the results should not be compared with those reached by electric or horse lines elsewhere; and I regret that similar statements of the elements of cost of operating such lines were not brought out in the discussion.

Mr. Nichols' statement that the showing is not a good one for cable roads is true only so far as the Kansas City line referred to represents an investment, but it is not true as applied to the mechanical results. If the distribution of operating expenses given in the paper is analyzed, and it is remembered that these cars only carried 1.9 passengers

per car-mile, it will be seen that with a larger business the receipts would increase very much more rapidly than the expenses.

The Kansas City line could not be operated with horses or with electricity as cheaply as with the cables, and give the same service; and while it seems to be a case where the travel does not justify the service, it must be remembered that when the lines were built the population of the city had increased 230% in the previous seven years, and that it then fell off 30% in the following three years, and is now again increasing. The line was selected for the purposes of the paper, as showing one extreme of the range of application of the cable, and it would have been possible to cite the case of a road where the cost of construction and that of operating per car-mile are about the same as in the Kansas City case, but where the total cost of operation is less than 40% of the gross receipts.

The cases of change from cable to electric traction do not, in themselves, prove anything. For instance, it is evident that the Jersey City road referred to by Mr. Brush could not afford to operate two miles of line with two methods of traction, each involving a special organization, and the conditions of operating this mile of elevated road differ in so many respects from those affecting a railway in a city street as to length of line propelled from one power-house, number of stops, size of cars, etc., that any comparison would be uninstructive.

The question as to the use of a shallow conduit raised by Mr. Tratman is very pertinent to a consideration, both of first cost and operating expense. There are, doubtless, some conditions under which a construction like that at Butte City would be justifiable; but it has always seemed to me objectionable in many ways, and I believe the amount that can be saved is less than is commonly supposed, or than will justify the sacrifice of operating economy and convenience. The items of cost which are affected are not a large proportion of the whole, and it is very doubtful if they can be reduced, all other things being equal, more than $15 000 per mile of double track, which certainly does not compensate for the increased cost of cleaning the conduits, maintaining pulley-pits, drainage, and adding largely to loss of business and delay in case of a stranded rope.

The Kansas City line, with a 38-in. tube and 14-in. pulleys, has no depressed carrier-pulley pits, and the company probably saves more than the interest on $15 000 in not having to maintain some 330 pulley-pit drains and keep them free from tar.